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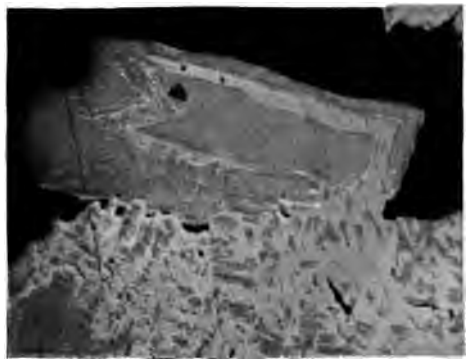

FIG. 1.

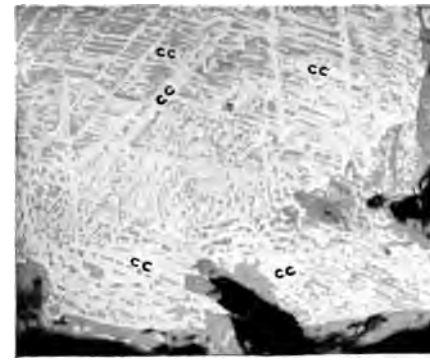

FIG. 2.

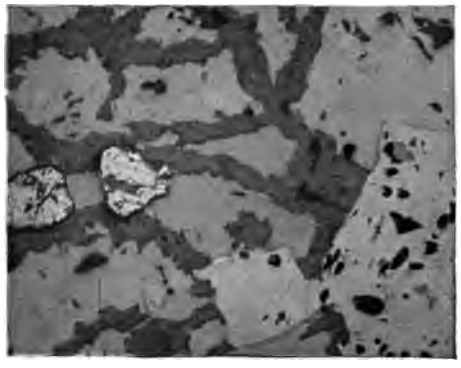

FIG. 3.

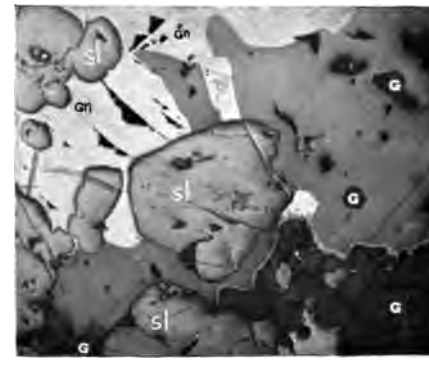

FIG. 4.

KEY

Bornite		"Blue" chalcocite	
Chalcopyrite		Chalcocite	cc
Covellite		Galena	gn
Pyrite		Gangue	G
Sphalerite	Sl	Pits are black	

PLATE I

Photomicrographs of polished sections by reflected light; colored to show the actual appearance of the minerals under the microscope.

FIG. 1. A bornite crystal from Redruth, Cornwall, showing symmetrically arranged inclusions of chalcopyrite. × 40 diam.

FIG. 2. A "bornite" crystal from Butte, Montana. This has the crystal form of bornite, but only the exterior is composed entirely of this mineral. The interior is nearly all "lattice" structure of bornite and chalcocite. × 30 diam.

FIG. 3. Secondary enrichment, from Butte, Montana. The section shows bornite, chalcopyrite, and a little pyrite, all primary, and veinlets of covellite, secondary. The enrichment is "selective," as the covellite has replaced bornite but not chalcopyrite. × 30 diam.

FIG. 4. Typical primary structure. This specimen is from Tanalyk, Siberia, and shows bornite, sphalerite, galena, chalcopyrite, barite gangue, and a very little secondary "blue" chalcocite. × 40 diam.

MICROSCOPICAL DETERMINATION
OF THE
OPAQUE MINERALS

AN AID TO THE STUDY OF ORES

BY
JOSEPH MURDOCH, PH. D.
Geologist, Secondary Enrichment Investigation

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FIRST THOUSAND

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PREFACE

ANALYSIS, that valuable tool of Science, can obviously be used only when the basal elements or units are recognized and understood. In geologic science it was early realized that a far greater insight into the character and significance of rocks than that afforded by their bulk composition is gained by knowledge of the kinds and proportions of their constituent minerals, which stand in relation to geology much as do the elements to chemistry. In consequence, mineralogy changed from an engaging phase of the collecting mania to a fundamental requisite in our study of the rocks, and microscopic petrography evolved as its specialized application to these natural associations of the minerals, whereby understanding of the nature and origin of materials forming our planet has been greatly extended.

One class of geologic bodies, the ores, relatively neglected in earlier stages of geologic advance, have of late years received increasing attention, partly because of their inherent interest, partly because they so sensitively record as to illuminate many complex geologic processes, but above all because of their enormous economic importance. Microscopic study of ores, however, was on a basis now known to be one-sided and inadequate, until application of the reflecting microscope, virtually beginning with Campbell's paper in 1906, permitted as minute and satisfactory observation of the opaque, metalliferous minerals, as had long been possible for the transparent varieties. This new method, quickly adopted by numerous American investigators, has already demonstrated its immeasurable value and is rapidly disclosing new and unsuspected truths regarding the opaque minerals. Indeed, it opens an entire new field of geologic science that promises to do for the ores what petrography has done for the rocks; for this the name " Mineralography " is herein proposed.

One serious handicap, lack of adequate means for identifying the mineral varieties, has hindered the fullest development and delayed wider adoption of this new method. Several lists of

properties of certain minerals and one or two essays at more systematic identification have appeared. However, the necessity for completeness, emphasized by Dana, for mineral determination in general, is even greater for the opaque varieties, owing to the closely similar properties of many. In other words, no determinative scheme for the opaque minerals can be satisfactory or reliable unless it includes them all. It cannot be concluded, for example, that a given mineral grain is tetrahedrite, because in certain tests it behaves like that species — it is necessary to prove that the grain in question actually *is* tetrahedrite and not something else, such as bournonite or polybasite, which closely resemble it in many ways; even the probabilities of the case cannot be relied upon, for it is now evident that many supposedly rare minerals are actually rather common in sulphide ores, are often of important geologic significance, and can in no case be safely ignored.

The scheme of determination of opaque minerals here presented embraces nearly every species of recognized identity that could be secured from the principal mineral collections of the United States, and thus includes many names probably familiar only to the professional mineralogist. One, who, like the geologist of a mine, may wish simply to examine the intimate relations of the minerals in a familiar ore, might therefore conclude that this treatise is too purely scientific and detailed for the needs of a busy, practical man. But he may be assured that even the simplest sulphide ore is more than likely to hold unsuspected constituents whose identity and significance, when determined, may prove of direct value.

Nor is specialized training or technique a pre-requisite to intelligent use of this plan of identification. Intricacies of crystallography and optics, essential to thin-section petrography, and generally mastered only under expert instruction, are not here involved; absence of the diagnostic optical properties of transparent minerals is balanced by ease of applying physical and chemical tests to the polished surface; even the microchemical reactions need not be understood to be used correctly. Practically the only requirement is to follow the simple directions indicated and the plan of indexing employed will lead almost automatically to the proper result. The entire scheme may be mastered by any one possessing common sense and a good eye.

In the matter of equipment, likewise, the demands are modest. Though elaborate instruments are advisable under certain circumstances, satisfactory results may be secured with the simplest outfit. Almost any microscope, for whatever purpose designed, may be adapted for this study at slight expense by attaching a prism reflector that permits daylight illumination. Or a satisfactory microscope may be had complete for less than $30.00. Mounting clay, glass tubing, and a few reagents complete the necessary equipment for examination, while the specimens may be prepared without delay by means of a file, emery cloth, chamois skin and rouge, if better means are not at hand. For the opaque minerals this determinative method should in time largely supplant blowpipe analysis, since it can in most cases yield better and quicker results with equal or greater simplicity, and perhaps as cheaply, if widely adopted.

Notwithstanding its fitness for elementary and for practical determinative uses, this text is intended equally for serious research. Mineralographic methods show that to a far greater degree than is true of the transparent species, the sulphide minerals tend to be microscopically mingled and intergrown in most intimate fashion, also that they may undergo serious alteration of which no outward sign may exist. In consequence, the composition ascribed to many species is discredited, the right to stand as independent species is disproved for others, and new species as yet unnamed have appeared, — even in specimens from the best-known collections of the country identified unquestionably with the greatest accuracy possible hitherto. In short, the mineralogy of the sulphides needs complete revision. Henceforth, he who describes or analyzes an opaque mineral, without first establishing its purity by closest mineralographic scrutiny, discounts his own reliability and that of his results.

In more practical directions, the wide applicability of this method of mineral investigation may be indicated by a list of typical problems it has solved in materials submitted to the Harvard laboratories:

(*a*) Method of occurrence and state of combination of gold, silver and other metals in ores as affecting choice of treatment to be adopted.

(*b*) Condition of metals lost in mill tailings (up to 100-mesh powders) and in slags, that suitable improvements in recovery may be applied.

(*c*) Extent and effect of roasting and of subsequent leaching of sulphide-bearing tailings from concentration.

(*d*) Character of furnace mattes, whether homogeneous or complex.

(*e*) Various practical geological problems difficult or impossible of solution otherwise, such as determining whether metal values in churn-drill pulps are primary or are due wholly or in part to secondary enrichment; also distinction between primary and secondary chalcocite.

The investigation embodied in this book originated as one of the essential preliminaries to a study of mineral occurrence and alteration being carried on by the Secondary Enrichment Investigation. It has been steadily pursued by Dr. Murdoch since 1911 and has had the benefit of trial in actual practice by members of the Secondary Enrichment staff and in the Harvard laboratories during the last two years, also in the Geological Department of the Massachusetts Institute of Technology during the past year.

L. C. GRATON.

CAMBRIDGE, MASS.
August, 1915.

CONTENTS

	PAGE
FRONTISPIECE	
PREFACE	iii–vi
INTRODUCTION	1
History	1
Importance of the Subject	3
Previous Work	4
Scope of Present Work	14
Bibliography	16
TECHNIQUE OF MINERALOGRAPHY	19
Polishing	19
Mounting	23
Examination	24
Magnification	25
Photographing	25
Color Comparison	26
Hardness Determination	29
Microchemical Tests	30
Method of Application	30
Reactions	31
Reagents	32
MINERAL COMPOSITION AND IDENTITY	33
Observed Mixtures	36
Probable Mixtures and Doubtful Minerals	38
PLAN OF CLASSIFICATION	40
Color	40
Colored	40
White	40
Gray	41
Transparent and Gangue Minerals	41
Effect of Surface on Color	42
Hardness	42
Microchemical Tests	42
Explanation of Tables	42
Directions for Use	42
Examples	43
Cross-references	44
Abbreviations	45
Outline of the Classification	47
TABLES FOR MINERAL IDENTIFICATION	57–152
MISCELLANEOUS TABLES	153
Condensed Determinative Table	154
Odor and Streak of Minerals	156
Minerals Tabulated by Elements	157
INDEX OF MINERALS	163

MICROSCOPICAL DETERMINATION OF THE OPAQUE MINERALS

INTRODUCTION

HISTORY

THE microscope was first applied to the study of thin sections of transparent minerals in 1828 by Nicol,[41] but the first practical use of it in studying thin sections was made in 1851 by Sorby.[40] This method of investigation has now been brought to a high point of efficiency and perfection. By means of the petrographic microscope, transparent minerals can be identified, and their most minute relationships observed, so that this instrument has gone far towards solving many of the important problems connected with ore and rock genesis, mineral constitution and alteration. The ordinary petrographic microscope is thus entirely satisfactory for the study of minerals which appear transparent in thin section, but, for the following reasons, loses much of its value when applied without modification to the study of ores, in which most of the important minerals are opaque.

In grinding a thin section, one of the fundamental requisites is to secure a plate of uniform thickness, as nearly plane as possible on both sides, with no difference in relief developed between hard and soft minerals. In this way comparison, which would not be possible otherwise, may be made of the different optical properties of minerals. But even with modern methods of preparation, if the surface is ground so that the harder minerals are perfectly smooth and shiny, the softer ones will be polished out, and the section will go to pieces; consequently the best that can be done in producing the plate of uniform thickness is to leave its surface microscopically rough. When observed by means of reflected light, the opaque minerals in such a section appear so rough that only the larger relations are usually apparent and they reflect in the desired direction so little light, that it is frequently

Note. — The determinative tables of this book, in practically their present form, constitute the principal portion of a thesis presented as part of the requirement for the degree of Doctor of Philosophy at Harvard University.

difficult or impossible to differentiate between closely similar minerals, without some further means of testing. Moreover, with vertical illumination, the coverglass on a thin section reflects much of the light before it reaches the section, so a dim image is produced, and the difficulty of accurate observation is increased. Until recently, however, most microscopic investigation of the sulphide minerals has been accomplished in this way.

In 1814, Berzelius[6] polished a section of pyrrhotite, in the hope of ascertaining why the composition was variable, and found another sulphide intergrown with it, showing a different color. He does not mention using a microscope in this examination. In 1863, Sorby[40] published an account of the microscopic examination of polished surfaces of iron. His methods of examination were practically those used today by metallographers, though of course the apparatus and methods of polishing have since been improved. This marked the beginning of the science of metallography, but the method was not applied to the examination of opaque minerals until 1885, when Baumhauer[4] polished some bornite and noted microscopically admixed chalcocite, chalcopyrite and galena, and gave some micro-drawings of the sections. Then, in 1887, A. A. Julien,[21] in studying pyrite, examined the smooth and etched natural surfaces of crystals with the Sorby reflecting microscope. He did not artificially polish any of his specimens. In 1904, E. Hussak[19] studied microscopically some polished surfaces of titaniferous magnetite from Brazil, and also etched and photographed them.

About 1900, William Campbell, a metallurgist, polished and examined under the metallographic microscope, some specimens of natural pyrrhotite in order to ascertain, if possible, the cause of their magnetic quality; he was at once so much impressed with the possibilities of this method for the study of opaque ores, that he determined to pursue the subject further. In 1906 he published a paper[12] describing rather fully the application of metallographic methods to opaque minerals, giving details of manipulation and examination of specimens. This paper, in which for the first time was emphasized the extreme value to the geologist and mineralogist of the method so successfully employed for metals and alloys, may be said to mark the beginning of the serious application of the reflecting microscope to opaque ores. Though Campbell's paper attracted a considerable

WHITE COLORE

amount of attention at the time of its publication, for several years following little was published involving the use of this method. More recently there has been rapidly increasing evidence of the use of this means of examination by students of mining geology, though its practice is still mainly confined to this country.

IMPORTANCE OF THE SUBJECT

The examination of opaque minerals and ores by the reflecting microscope is now established as a definite branch of geologic investigation, and merits a designation of its own. For this, the term " mineralography " is suggested; it is analogous to " petrography," which now commonly implies the microscopic study of rocks, and to " metallography," the microscopic study of metals and alloys, while its etymology signifies its relation to the broad science, mineralogy, as petrography is related to the more inclusive subject, petrology. The possible objection that the subject is really narrower than its name implies, since it deals with only one division of minerals, is also applicable to crystallography, which does not claim to usurp the entire field of crystal study, and to metallography, which deals only with certain features of metals; and indeed, it is because petrography has in practice been limited to less than its name implies, that there is room and need for this new subject, mineralography. Petrography and mineralography are complementary, and together will cover both the rocks and the ores.

By the methods of mineralography the appearance and structures of opaque minerals can be observed as accurately and easily as those of transparent species in the ordinary thin section. Mining geologists are beginning to realize that the careful microscopic study they have been giving to the transparent gangue minerals in ores yields only a part of the information required, and that it is necessary to gain equally detailed and accurate knowledge concerning the microscopic relations of the opaque minerals, which are, in fact, the most important constituents of most ores. It is in this direction that the subject will find its widest economic application.

Mineralography should also be of the greatest assistance to the mineralogist, in determining the purity of opaque minerals. Examination of several thousand ore and mineral specimens shows

difficult or impossible to differentiate between closely similar minerals, without some further means of testing. Moreover, with vertical illumination, the coverglass on a thin section reflects much of the light before it reaches the section, so a dim image is produced, and the difficulty of accurate observation is increased. Until recently, however, most microscopic investigation of the sulphide minerals has been accomplished in this way.

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Mineralography should also be of the greatest assistance to the mineralogist, in determining the purity of opaque minerals. Examination of several thousand ore and mineral specimens shows

Magnetite. — Steel gray color. Polishes very well* but more slowly than chalcopyrite. H. = 5.5 – 6.5. It etches differentially along cleavage planes, often yielding a " grid-iron " structure.

Pentlandite. — Light bronze color. Polishes better than pyrrhotite; is not so brittle. H. = 4. Sometimes shows a distinct cleavage. Easily distinguished from pyrrhotite by etching.

Pyrite. — Pale brass color. Polishes with difficulty. Retains scratches long after other constituents. H. = 6 – 6.5; therefore it polishes in relief.

Pyrrhotite. — Light bronze color, similar to pentlandite. More brittle than pentlandite and shows a more pitted surface. H. = 4. By immersing in hot HCl (1 acid to 1 water) pyrrhotite is attacked, pentlandite is not.

1908 — Simpson[37] summarized the characters of a few minerals as follows:

Bornite. — Copper red to pinchbeck brown in color. H. = 3. Easily attacked by nitric acid. This acid gives the bornite a tarnished appearance. When with pyrite, an extremely smooth surface of this mineral is difficult to obtain, on account of the great difference in hardness between the two.

Chalcocite. — Blackish lead gray in color. H. = 2. When etched with nitric acid, a distinct blue color is obtained. This is the best means of identification.

Chalcopyrite. — Color, brass yellow. H. = 3.5 – 4. The color is the best characteristic. Soluble in nitric acid.

Enargite. — Color steel gray to grayish black. H. = 3. Soluble in Aqua Regia only. Its insolubility in nitric acid is the best means of distinguishing it from chalcocite.

Pyrite. — Its pale brass yellow color is one of the best means of identification. On account of its hardness, it retains scratches long after the other constituents. H. = 6 – 6.5. Etched by nitric acid.

* Probably because in the Sudbury ores, magnetite is present in small grains in a softer matrix.

These colors were apparently taken by Simpson from the descriptions in a text-book on mineralogy, and do not in all cases represent the colors on the polished surface.

— Warren[44] described briefly the appearance of magnetite and ilmenite (in titaniferous magnetite) etched by strong HCl, and unetched, saying that the ilmenite appeared as bright gray, narrow strips, and the magnetite as dull black.

— Koenigsberger[22] devised a method for observing the optical character of opaque minerals in reflected light. He used a reflecting prism for a vertical illuminator, and employed a Savart plate of calcite, a movable plate of plane glass and one nicol. The magnification recommended was about 100 diameters. The apparatus was adjusted with an isotropic metallic mirror so that the Savart bands were not visible when the glass plate was horizontal, but appeared when this was rotated vertically through a large angle. Isotropic minerals behave like the glass, but anisotropic minerals show the Savart bands, with four positions of extinction and four of greatest brightness, as the stage is rotated. His claims are as follows: He could distinguish the relation between optic and crystal symmetry by means of a contrast plate attached in front of the prism illuminator. By the determination of extinction angles on oriented sections, he could discriminate between monoclinic and orthorhombic minerals. If a mineral is weakly anisotropic, it may be confused with isotropic minerals. Some minerals are isotropic for one color of light, and not for another. He could tell whether or not symmetry is reached by hidden twinning. When crystal faces are not available, isotropism or anisotropism can be determined more easily this way than by study of any physical properties. He found that a basal plate of molybdenite was isotropic. Hematite, pyrite, chromite, franklinite, argentite and tetrahedrite are also isotropic on basal sections. Pyrrhotite, parallel to the base, is made up of feebly anisotropic parts. Glaucodot is feebly anisotropic perpendicular to the vertical axis; chalcopyrite is strongly anisotropic. Chalcocite is isotropic on the base. Manganite, columbite, hematite and ilmenite are quite strongly anisotropic.

For a fuller description of Koenigsberger's apparatus and methods the reader is referred to his paper,[22] or the translated abstract in Winchell's Optical Mineralogy.[46] He laid great stress on the necessity of very careful and perfect polish, and recom-

mended chrome oxide for the final polish. Little success appears to have attended the trial of this method in this country and the validity of some of his premises is not universally accepted.

1911. — Laney[24] etched chalcocite with nitric acid, and developed cleavages in it, which he suggested were prismatic and basal.

— Leo[26] investigated a number of minerals on the polished surface, and gave an elaborate table of tarnish colors and coatings formed by various reagents. His plan involved etching the whole specimen, and moreover it appears that he was unable to secure a good polish on his minerals, so that the difficulty of identification, especially of small areas, seems too great for practical use of his methods. Below is given a list of the minerals studied by Leo.

Pyrrhotite	Pyrite	Barnhardtite [mixture]
Pentlandite	Marcasite	Linnæite
Millerite	Bornite	Cubanite [mixture]
Horbachite	Chalcopyrite	Polydymite

— Lincoln[27] gave a valuable table for the identification of gold minerals and some associated minerals. This table is reproduced on the following page.

1912. — Bastin[2] mentioned galena, chalcopyrite, sphalerite, pyrite, polybasite, proustite and stephanite, but does not give determinative criteria for all. He noted the triangular pits in galena, and gave the following characteristics of polybasite. " The freshly polished surface (of polybasite) has much the appearance of chalcocite . . . but unlike chalcocite it does not tarnish or etch readily when treated with HNO_3. When treated with concentrated HNO_3, a tarnish begins to appear on this mineral at about the same time that it appears on the chalcopyrite of the ore. When the chalcopyrite shows a faint peacock tarnish the polybasite exhibits a yellowish brown color, in places showing slight iridescence. In specimens where the polybasite is present in too small amounts to be isolated, it may be identified in the polished section by this characteristic behavior with HNO_3."

— Singewald[38] said that on the polished surface etched with hot HCl, ilmenite appears bright and unaltered, and magnetite is somewhat dull black.

— Brunton[10] described the same minerals as Singewald. He could see no difference on the unetched surface between ilmenite and magnetite. He also polished rutile, and said it has a reddish tinge.

IDENTIFICATION OF GOLD MINERALS ON POLISHED SURFACES

Mineral	Color	Texture	Effect of treatment with				
			HNO_3, 1:1	1:2	1:4	HCl, 1:1	Hg
Native gold	Deep yellow	Smooth	0	0	0	0	Amalgamation
Chalcopyrite	Deep yellow	Rough	0	0	0	0	0
Pyrite	Pale yellow	Slightly rough	Black tarnish	Black tarnish	0	0	0
Marcasite	Pale yellow	Slightly rough	Black tarnish	Black tarnish	0	0	0
Pyrrhotite	Pale reddish yellow	Very rough	0	0	0	0	0
Calaverite	Pale yellow	Smooth	Bronze tarnish	Bronze tarnish	0	0	0
Sylvanite	Pale yellow	Smooth	Bronze tarnish	Bronze tarnish	0	0	0
Nagyagite	White	Smooth	Gray tarnish	0	0	0	0
Petzite	White	Smooth	Brown & blue tarnish	Brown & blue tarnish	0	Gray tarnish	0
Hessite	White	Smooth	Brown & blue tarnish	Brown & blue tarnish	0	Gray tarnish	0
Galenite	White	Smooth	Brown & blue tarnish	Brown & blue tarnish	Brown & blue tarnish	Gray tarnish	0
Other common white minerals	White	.....	.....	0	0	.....	.....

1913. — Graton and Murdoch[17] gave a brief account of the significance of the commoner sulphides in ores of copper, with no attempt to give other determinative characteristics than are implied by manner of occurrence.

1914. — Thompson[41] described the appearance of the following minerals.

Chalcopyrite, smooth, bright brass color.

Pyrrhotite, generally pitted, distinctive light bronze.

Galena, dazzling white.

Sphalerite, smooth, blue.

Chalcocite, etched by nitric acid.

Tetrahedrite
Bornite } no criteria given.

— Bruce[9] has assembled a number of tests made by previous investigators, and has added a considerable number made by himself. In addition he gave brief notes on manipulation and chemical tests, and listed a few reactions for elements, as follows:

Iron. — Fresh $K_4Fe(CN)_6$ + acid gives deep blue.

Nickel. — First a mixture of HNO_3 and tartaric acid is applied, and allowed to evaporate, then touched with a drop of dimethylglyoxime, freshly made ammoniacal, which gives a brilliant red.

Copper. — A mixture of HNO_3 and $K_4Fe(CN)_6$ gives a deep red. With iron present, also, this is followed by green.

Manganese. — Most manganese minerals are soluble in HCl, giving a deep brown solution, which is rendered colorless by addition of H_2O_2.

Silver. — First HNO_3, which is allowed to evaporate, then is touched with HCl, giving a white precipitate. Lead and mercury minerals give the same.

Bismuth. — First HNO_3, evaporated, then HCl added. Then water is added, producing a white precipitate.

Bruce's table of tests is given below.

I. Mineral by Inclined Illumination is Yellow.

A. Etched by HCl.

Pyrrhotite. — Bronze yellow. Surface rough. Reacts for Fe.

B. Etched by HNO_3, not by HCl.

(*a*) Without noticeable tarnish or deposit.

Pyrite. — Pale yellow. Slightly rough. Reacts for Fe.

Marcasite. — Pale yellow. Slightly rough. Reacts for Fe. Precipitates Ag (?).

Millerite. — Slightly rough. Reacts for Ni.

(*b*) With tarnish.

Chalcopyrite. — Deep yellow. Rough. Reacts for Fe and Cu. Iridescent tarnish.

C. Not attacked by single acids.

Gold. — Deep yellow. Smooth. Amalgamates with Hg.

II. Mineral is White

A. Etched by HCl.

B. Etched by HNO_3.

(*a*) With no tarnish or deposit.

Smaltite. — Rough with bright facets. Gives Ni test.

Arsenopyrite. — Rough with bright facets. Becomes gray with reddish spots. — Reacts for Fe, not for Ni.

Leucopyrite.* — White. Very rough. Reacts for Fe.

Silver. — Smooth. Reacts for Ag.

Bismuth. — Smooth. Reacts for Bi.

(*b*) With deposit.

Arsenic. — Chalky white deposit.

Antimony. — Chalky white deposit.

C. Unattacked by single cold acids.

Cobaltite. — Slightly rough. Etched by HNO_3.

Niccolite. — Slightly rough with reddish tinge. Treated with Aqua Regia reacts for Ni.

III. Mineral is Black or Grayish Black

A. Etched by HCl.

Magnetite. — Shows intersecting parting planes. Etches easily. Fe reaction.

Franklinite. — Fairly smooth. Etches less readily than magnetite.

Ilmenite. — Fairly smooth. Etches very slowly.

Hematite. — Steel gray. Smooth. Red streak.

Manganite. — Dull black. Brown solution.

Psilomelane. — Brown and black areas. Brown solution.

Braunite. — Black. Etches to bluish black. Brown solution.

* Same as löllingite.

Alabandite. — Smooth, grayish black. Very easily attacked. (40 sec.)

Pyrolusite. — Black fibrous surface. Soft. Brown solution.

B. Etched by HNO_3, not by HCl.

(*a*) Without tarnish.

Enargite. — Dull grayish black. Etches to fibrous structure. Cu test.

Argentite. — Smooth dull black. Ag test. Sectile.

Stephanite. — Smooth dull black. Ag test.

(*b*) With a tarnish.

Chalcocite. — Smooth black. Etched to a bluish tarnish, later becoming peacock colors.

Bornite. — Pitted. Purple color. Etches to a peacock tarnish. Reacts for both Fe and Cu.

(*c*) With a deposit.

Galena. — Smooth black. Etches easily, with a yellow deposit.

Bournonite. — Smooth dull black. Etches easily, with yellowish opalescent deposit. Cu test.

Stibnite. — Smooth dull black. Etches fairly slowly to a fibrous structure with a chalky deposit.

Tetrahedrite. — Smooth. Bluish black. Etches with an opalescent deposit. Reacts for copper.

C. Unattacked by single acids.

Molybdenite.

Chromite.

Cassiterite. — Black deposit by electric etching.

Columbite.

This paper, dealing with 37 species, is the most extensive so far published on opaque mineral identification, and is intended as a summary of results up to date. In etching, Bruce used concentrated acids for periods of several minutes, so that the reactions are in many cases quite different from those produced by the more dilute reagents and shorter time of etching advocated in the present book. It is not clear, however, why oblique illumination alone has been employed for Bruce's determinations. This has been found of considerable service in examining transparent sulphides, like sphalerite or ruby silver, but this result may easily be obtained by cutting off the vertical illumination temporarily. Experience has indicated that vertical illumination

is more effective in the case of opaque minerals, since the perfectly smooth surface of any opaque substance, regardless of its real color, will appear black, or nearly so, with oblique light, except with very low powers; and a rough surface, which alone will show the true color of the mineral by inclined illumination, is extremely undesirable from many standpoints.

— Rogers[44] stated that magnetite has a rough surface; hematite is rather smooth, faintly scratched; bornite and chalcopyrite are easily recognized by their colors. He also said that with plane polarized light, covellite shows pleochroism, deep blue (parallel to the plane of vibration of the nicol) to light blue (perpendicular to this).

— Kraus and Goldsberry[23] examined polished bornite crystals to ascertain their purity, and analyzed material from the same crystals, but gave no determinative criteria for identifying this mineral.

1915. — Chamot[15] published a valuable book on microchemistry, giving microchemical tests for the elements, manipulation, etc., and methods of polishing, intended especially for metals and alloys, but applicable to a great extent to opaque minerals as well.

— Thompson[43] mentioned the following minerals but gave no criteria for their identification: Pyrite, chalcocite, bornite, chalcopyrite, covellite, enargite, sphalerite, tetrahedrite and a white alteration product of enargite. Following earlier work by others, he etched covellite and enargite with KCN and stated that it developed a structure in them.

From this summary it is evident that a considerable number of the commoner and some of the rarer opaque minerals have been studied and described, and in addition undoubtedly much valuable work of this nature has been done, but not yet published. Nevertheless, no systematic attempt appears to have been made to cover the whole field of the opaque minerals, and little attention has been paid to standardization of methods, many of which appear to have been developed without regard to previous work. In consequence, much effort has been wasted in duplication, and variable results have often been obtained, while most of the opaque minerals have been left without means of determination by the microscopic method.

SCOPE OF PRESENT WORK

In 1911, a mineralographic investigation of some of the sulphide ores of copper was undertaken by L. C. Graton and the author.[17] It was at once seen to be very essential to know what the different ore minerals looked like, and how they behaved chemically, under the microscope. Accordingly, many previously determined specimens of the commoner opaque minerals were assembled and studied, and thus it was possible to reduce materially the uncertainties in determination, and often in interpretation of structure. The author has continued the determinative part of this work in the laboratory of Mining Geology of Harvard University, and the present book is the result of investigations carried on over a period of nearly four years. It does not discuss the paragenesis or significance of the minerals and structures involved. The great importance of these problems is evident, but this book has been strictly confined to mineral identification. It is devoted solely to determination of the physical and chemical properties of the opaque minerals, as observed under the microscope, with a classification of these data in such form as to permit their ready application to problems of identification, somewhat after the manner of Brush and Penfield's or Johannsen's determinative tables. The primary object has been the production of a practical and simple scheme of mineral identification, and accordingly only those lines of investigation have been pursued which contributed directly toward this end. Further work will probably modify some of the results attained, especially when extended to additional associations of minerals and to sub-species and variations not yet studied. The methods of investigation will also doubtless be improved, but the present results have been found to afford a practical means of mineral determination and may serve as a ground work for future research in a field that promises to be of great importance. In a work dealing with so new a field, however, errors and omissions are likely to be found, and notice of any such will be much appreciated.

The collection studied includes 186 definite minerals, a few of which are as yet unidentified, or perhaps new; a few mixtures, with known and with unknown constituents, which have been previously regarded as true minerals, and as such have been given mineral names; and some definite varieties of known species, such as the argentiferous tetrahedrite, freibergite. The minerals have

been assembled from the collections of various mineralogical museums, with some from private collections and mineral dealers. The list comprises a few metallic elements and oxides, and practically all the minerals of the sulphide and sulpho-salt groups, including selenides, tellurides and arsenides. A few, like cuprite or the ruby silvers, are transparent, but are included because of their character and associations. There are a number of named species not represented, but only a few of these are true minerals, most of them being admittedly mixtures, or very dubious.

In the case of each mineral, specimens from two or more localities have been secured and studied, whenever possible, as a check on the uniformity of the findings, and specimens previously determined by chemical or crystallographic methods have been given preference in every instance. Nevertheless, many species are represented by but a single specimen, and in order that the reader may judge of the reliability of the determination, the number of localities from which specimens have been secured and studied has been put in parentheses after each mineral name in the Index of Minerals. (n) indicates more than five localities. When only one specimen was available, or when the mineral is dubious, a letter or symbol is added to indicate the value of the description. Thus: G = Reliable. F = Probably reliable. ? = Doubtful. For example, there is only one specimen of glaucodot in the collection, but it is a large crystal, definitely identified. This, of course, increases the value of the observations on this mineral, but does not assure that its properties would be constant in different localities. It has been found, however, that specimens of the same mineral from different localities usually correspond very closely. For the commoner minerals, especially, this fact has been established by observations on hundreds of specimens of ore from various parts of the world.

The author wishes especially to express his indebtedness to Professor L. C. Graton, of Harvard University, for much valuable advice and helpful criticism throughout this work, and for supplying much material of great value to the study. Professor J. E. Wolff and Professor Charles Palache, of Harvard University, have very kindly furnished much material from the Museum Collections, and have given information that has been of great assistance. Professor Waldemar Lindgren, of the Massachusetts Institute of Technology, has been kind enough to give this

work, in manuscript form, a practical trial and to offer valuable suggestions. To the generosity of Mr. W. A. Roebling of Trenton, N. J., is due the opportunity to study many very rare and valuable specimens of his collection, thereby adding greatly to the completeness of the work. Much valuable material has been obtained through the courtesy and generosity of Drs. G. P. Merrill and J. E. Pogue of the National Museum at Washington; Professor W. E. Ford of Yale University; and Dr. L. P. Gratacap of the American Museum of Natural History, N. Y., to whom grateful acknowledgment is made. The spirit which has led numerous practicing geologists and engineers to transmit interesting and unusual materials from many parts of the world is also much appreciated.

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TECHNIQUE OF MINERALOGRAPHY

POLISHING

The mineral to be examined should be polished so that it has rather large areas shiny, or very smooth, and free from pits, and should have few or no scratches. This relatively perfect polish is necessary in this work, as a much pitted or scratched surface often obscures the true color of a mineral, and may even modify somewhat the microchemical reactions. For example, some of the hard minerals, like hematite or magnetite, appear gray instead of white, if the surface has not at least fair-sized areas free from pits. Minerals, like pyrite, which scratch instead of pitting, should not be polished too shiny after they have reached a condition permitting identification, as this would develop too much relief as compared with adjacent softer minerals — a thing which is not desirable.

Campbell[12] and Ray[31] give accounts of polishing methods for which the reader is referred to their respective papers. Other workers have variations of their own, and individual preferences will differ. The following method has been found most satisfactory in the opinion of the author.

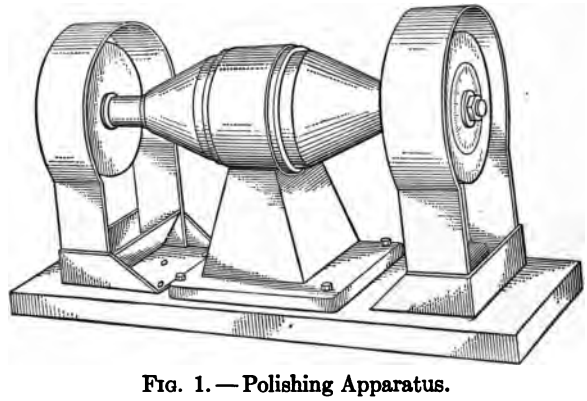


FIG. 1. — Polishing Apparatus.

The grinding apparatus used is Sauveur's machine for polishing steel. (See Fig. 1.) It consists of a horizontal spindle with two vertical iron discs 8 inches diameter and $\frac{3}{4}$ inch thick, run at about

1200 revolutions per minute. This gives four polishing surfaces. The first is a $\frac{1}{4}$-inch carborundum wheel laid against one side of the first iron disc. The carborundum wheel that gives best results is a mixture of 40-, 60- and 80-mesh carborundum, soft-bonded, so it will not readily clog or grow dull.* On the other side of the first disc is stretched a heavy canvas cover, armed with 220-mesh carborundum powder, mixed with water to a thin pasty consistency, and applied to the revolving wheel with a flat brush about $1\frac{1}{2}$ inches wide. The other disc is covered on both sides with broadcloth, to which is similarly applied a very thin paste of tripoli powder, on one side, and of rouge on the other. The rouge and tripoli used in polishing steel are quite satisfactory for minerals, and if carborundum powder is not available, flour emery instead may be used on the canvas wheel.

Specimens varying in size from over two inches in diameter down to the smallest piece that can be held in the fingers may be handled on these wheels. Preferably, the rough chips are about half an inch to an inch square and half an inch thick, and with one fairly even side or face to begin with, as by polishing on this face, time is saved in the grinding. The surface may be most rapidly flattened by pressing it diagonally against the corner of the carborundum wheel, before applying it to the smooth side of the wheel.

The carborundum wheel is generally used dry, but may be fed with water if the specimen to be ground is brittle, or likely to be injured by heating. In either case, it is often advisable to cool the specimen from time to time by a moment's immersion in water. On delicate specimens, a diamond saw may be used instead of this wheel, but for general work, the carborundum wheel is more satisfactory and much cheaper. The purpose of the carborundum wheel is to cut a flat surface preparatory to the real polishing. It is also used to bevel off the edge of the ground face all the way around, which must be done to avoid the danger of tearing the cloth of the other wheels by sharp or irregular projections. When this has been done, the specimen and the hands are carefully rinsed, to remove any particles of carborundum or loose fragments of the specimen, and this procedure is repeated after the operation on each wheel has been completed and before passing to the next wheel.

* The Carborundum Company's specifications are as follows: Grit 403; Grade M; Bond B3.

Then the specimen is applied to the canvas wheel, which is kept wet and well supplied with carborundum powder. Here the pits produced by the coarse wheel are ground out, and the harder minerals, like magnetite or pyrite, are given practically whatever polish they are to receive. Little or no relief is developed here, and the wheel is very valuable for producing a plane surface free from pits. Most specimens should be kept here longest, so as to save time and trouble later on. Very soft or brittle specimens, like massive chalcocite, should be started on this wheel, to avoid "burning" or cracking by heat on the carborundum wheel. Considerable pressure may be applied here, but it is desirable that this be lessened at the end of grinding, to make the scratches less deep.

When the surface is plane and unpitted, and the specimen and hands have been rinsed, polishing on the third, or tripoli, wheel is begun. The specimen should not be pressed heavily, but only moderately, against this wheel. Here the softer minerals, such as chalcopyrite, are polished, though usually with fine scratches still visible. This wheel also develops relief, by attacking the softer without much affecting the harder constituents. Too great relief is not desirable, as the hard constituents would then stand high and prevent the formation of a flat surface on the softer ones, which, though shiny, would then appear grooved and uneven, and their relationships would be obscured. Moreover, these hard minerals, if projecting prominently, tear the surface of the cloth, and wear it out very rapidly. All these difficulties are avoided by removing most of the pits on the canvas wheel, and not polishing too long or too hard on the tripoli wheel.

When the softer minerals appear smooth, the specimen is again rinsed, and transferred to the last, or rouge, wheel. This usually does little more than give a burnish to the specimen, but in the case of chalcocite, or a similarly soft mineral, considerable polishing is done here, and the scratches from the tripoli wheel are removed. This final burnish is very important, but it is not usually necessary to polish on this wheel more than five or ten seconds. The specimen is then dried by wiping thoroughly with a soft cloth, or by rinsing in alcohol and drying in an air blast, as any moisture will injure the surface of the rouge block, to which the specimen is next transferred for the last step in its preparation. The rouge block consists of a piece of chamois skin stretched over a flat block of wood and fed with a little dry rouge. On this

the specimen is rubbed briskly, but without excessive pressure, for a few seconds, to give it a final burnish, and to remove any films or specks of dirt that may have adhered to the surface. The rouge block must be kept free from all grit and dirt, as this would scratch and mar the surface of the specimen. It should be kept covered, except when in actual use, and all mineral or dirt fragments removed by brushing.

After a moderate amount of practice, in which experience is gained as to the appropriate pressure to apply, and the minimum of time required to produce the desired effect, an average specimen may be polished in six or seven minutes.

Specimens too small to be held in the fingers may be polished by first mounting them in partly melted sealing wax, and a flat surface produced before the wax hardens by pressing the wax containing the chip, face down on a wet glass plate, or by laying the piece face down on a wet glass and running melted wax over it. Then the wax and specimen together may easily be polished. Of course it is not to be put on the dry carborundum wheel, as the heat of friction would melt the wax, but is to be started on the canvas.

For polishing powders, or small grains of minerals, the following procedure is convenient. A flat surface of sealing wax is softened, and the powder sprinkled thickly over this. It may be pressed in by the finger while the wax is still soft, or melted in by additional heat. Then the softened surface is pressed on a wet glass plate, so as to produce a flat surface, which is polished in the ordinary way, except that in the case of fine powders, the tripoli wheel is the coarsest one used. By this means, almost impalpable powders may be polished and studied, and it is especially valuable for the examination of churn drill pulps, mill tailings or concentrates, powders and minute fragments of synthetic minerals, or tiny crystals of rare minerals. In the case of crystals, polishing may be done in carefully oriented directions, and a number of oriented surfaces may be polished on a single piece. Crystal-lined vugs, or crusts of crystals, may be filled with melted wax and polished down carefully without destroying either the crystals or their arrangement or injuring the polishing wheels. Fusible alloys, or dental enamel, may be used instead of wax, especially for mineral grains that are hard and apt to tear out when polished.

The method of polishing outlined above, or a similar one, is very desirable as a time- and labor-saving arrangement, but is not absolutely essential. As a matter of fact, even at a remote mine or prospect, satisfactory polished sections may be secured without an excessive expenditure of time, with nothing more elaborate than a file or two, a number of sheets of emery paper of varying degrees of fineness, a strip of chamois skin and a little rouge. If a grindstone is available, of course much time can be saved in preparing a flat surface on the ore chips.

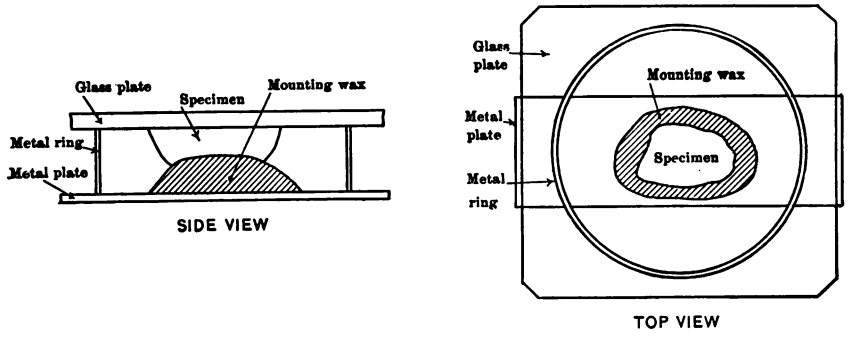


FIG. 2. — Method of Mounting.

MOUNTING

Specimens may be mounted for examination on the stage of the microscope in any one of a number of ways by which the polished surface is held perpendicular to the axis of the microscope. It has been found convenient to mount the specimen, by means of a lump of modeling wax, on a metal plate 3 inches long, 1 inch wide and $\frac{1}{8}$ inch thick. The polished surface is made parallel to the bottom of the mount by pressing it down with a piece of plate glass until this rests on the top of a metal ring of uniform height, conveniently about $\frac{7}{8}$ inch, which is placed temporarily on the steel plate and around the specimen. (See Fig. 2.) This is a modification of Campbell's cup method. The mounted specimen may then be placed on the microscope stage without need of further adjustment. To permit chemical and physical tests on the polished surface directly under the microscope, a type of instrument that holds the specimen with the polished surface upward should be used, but for other purposes, instruments employing inverted mounting are as satisfactory.

EXAMINATION

For the microscopic examination of polished surfaces of opaque minerals, an ordinary metallographic microscope is used. This carries a special reflector, called a " vertical illuminator," screwed into the microscope tube like an objective, by means of which light is directed vertically downward on the polished surface, and reflected back from this up through the instrument to the eye. Any ordinary microscope, that permits sufficient elevation of the tube to admit the vertical illuminator and the mounted specimen, may be used for this work. If the petrographic micro-

FIG. 3. — Prism Illuminator.

FIG. 4. — Plane Glass Illuminator.

FIG. 5. — Short-mounted Objective.

scope is used, the analyzer ordinarily should be thrown out. For use with daylight, the vertical illuminator is a totally reflecting prism (Fig. 3); with artificial light, more even illumination is secured by the use of a reflector consisting of a plane glass disc (Fig. 4).

If daylight is used, care must be taken also to avoid reflections from buildings, trees, or clouds, as these affect the colors of minerals. For the most accurate results, an open, cloudless sky is necessary; moreover it must not be too late in the afternoon, as the quality of light changes rapidly then, and becomes somewhat polarized. In using objectives of higher power than about 16 mm. by daylight, the short-mounted form (Fig. 5) should be used, as with the ordinary mounting only a narrow strip across the field is properly illuminated by the prism.

The most satisfactory artificial light has been found to be that of an electric arc, reduced in intensity by passing through a ground glass screen. This gives practically the same color values as daylight. The colors of minerals have been standardized by this light or daylight.

Methods of comparing colors under the microscope will be found on page 26. All bright oblique light should be shut off from the specimen by a screen which allows light from the side to fall only on the aperture of the vertical illuminator. This

will eliminate the confusion arising from the mingled effects of vertical and oblique light. For observing transparent minerals, the screen is removed, and the aperture of the vertical illuminator closed, so that oblique light alone falls on the surface, and by this means their color by transmitted light may be observed, even in very small grains.

MAGNIFICATION

The most convenient magnification for ordinary purposes is about 50 diameters, but frequently 200 may be employed to advantage. For very detailed examination, by artificial light, this may be increased to 800 or more (with an oil immersion objective). In daylight, 400 diameters is about the upper working limit, as above this the image is usually too faint and blurred to be observed accurately. In some cases a low power objective, or even a hand lens, may be used advantageously to observe the larger relationships of minerals.

PHOTOGRAPHING

Microphotographs of polished specimens can be made with little difficulty. They are very useful for purposes of record and comparison, and in written reports give a clearer idea of the material than could possibly be conveyed by a lengthy description. Microphotography may be accomplished by attaching a camera box to the end of the microscope, which itself serves as the camera lens. Artificial light is usually employed and the ground glass screen omitted, to permit of shorter exposures. In general, the equipment and procedure are the same as in metallography. The colors of the common minerals occurring in ores, however, such as chalcopyrite, bornite, covellite, etc., require the use of color screens to develop contrast between two or more minerals which in white light may have almost the same photographic intensity. For instance, with an ordinary contrast plate and no color screen, in the combinations bornite and chalcocite, covellite and chalcocite, and chalcopyrite and galena, the component minerals have practically the same color values, and often the contact between them is hardly visible. But with a monochromatic screen which will make one of each pair appear dark, beautiful results may be obtained.

For color screens, Wratten and Wainwright light filters have been used with great success in this sort of microphotography, and

the following grades have been employed: K2 = yellow; A = red; B = green; C = blue. The red of course can be used successfully only with panchromatic plates. The others can be used with Cramer Contrast or Seed L ortho, non-halation plates.

The following data will serve as a guide in photographing these or similar combinations of minerals.

WHITE LIGHT. — Cramer Contrast plate — sphalerite and galena; etched chalcocite; pyrite, galena, or chalcopyrite, in gangue.

YELLOW SCREEN. — Cramer Contrast plate — bornite and chalcocite; bornite and chalcopyrite; covellite and chalcocite; covellite and chalcopyrite; pyrite and chalcopyrite; "mottled chalcocite."

GREEN SCREEN. — Cramer Contrast or Seed L Ortho (n.h.) plate — same as with yellow screen, but Cramer Contrast requires very long exposure, and Seed plate does not give so bright a negative. The yellow screen is better in most cases.

BLUE SCREEN. — Cramer Contrast or Seed L Ortho plate — chalcopyrite and chalcocite; tennantite and enargite.

RED SCREEN. — Panchromatic plate — covellite and bornite.

The preceding paragraphs apply best to pairs of minerals, but when three or more are to be photographed the best combination to use is Seed's L Ortho, or a panchromatic plate* with the K2, or yellow screen. This will give nearly the true color values to a complex combination of minerals, such as sphalerite, galena, chalcopyrite, tennantite or tetrahedrite, bornite, and gangue, a not unusual assemblage in certain types of sulphide ore.

The table of exposures given on the following page is not complete, but covers the parts likely to be of use in ore photography, both as regards magnifications and combinations of minerals.

COLOR COMPARISON

The accurate determination of the colors of minerals is one of the most important steps in their identification, and for this reason demands careful attention. It is also one of the most difficult things to accomplish, and for the most precise distinctions requires a certain amount of practice. The importance of color is due to the fact that in reflected light more than three-quarters of the sulphide minerals are white, or nearly white, and in con-

* Very recently the Eastman Kodak Co. has put on the market the Wratten M Plate, especially designed for microscopic photography. It is highly efficient, and their accompanying booklet, "Photomicrography," is also highly to be recommended to workers in this line.

EXPOSURES

Screen	None	Green "B"			Yellow "K2"			Blue "C"			Red "A"
Plate	C.C.	SLO	C.C.	W+W	SLO	C.C.	W+W	SLO	C.C.	W+W'	W+W
Magnification:											
45	1/15	.....	...	....	..	2	....	...	..	....	....
55	1/10	.....	...	....	..	2½	....	....	..	....	....
65	½	1	60	2	2	3	½	1	..	1½	2
85	1	.....	1*15	....	..	4	....	...	..	....	....
130	2	2½	...	....	..	5	....	...	..	....	....
170	...	.....	...	....	..	7	....	...	..	....	....
250	...	3	2*	....	..	...	....	...	..	....	....
300	...	6	...	....	..	10	....	...	..	....	....
375	...	.....	3*	....	..	15	....	...	..	....	....
750	...	10	...	....	5−	...	....	...	..	....	....
840±	...	12	...	12+	5+	...	4	...	..	....	....
1670±	...	15	...	20	10	...	....	...	..	....	....

Key: — SLO = Seed L Ortho, non-halation plate.
C. C. = Cramer Contrast plate.
W + W = Wratten and Wainwright Panchromatic plate.
* = minutes. Ordinary figures indicate seconds.

Note. — These exposures are figured for the B. & L. Model D Balopticon, but the same proportions will hold for light of different intensity.

sequence comparatively delicate distinctions must be made to separate this large class into smaller groups which may be more readily sub-divided by microchemical tests. Fortunately many of these minerals possess various tints, such as creamy, or bluish, or grayish white, and may conveniently be separated into groups, by comparison with a standard. The primary standard is pure galena, and the position in the color scale of every white mineral is established by its appearance when compared with galena. There are also subordinate standards for the different qualities of white, such as silver (pure, not coin silver) for the creamy white minerals, tetrahedrite for the grayish white, and cuprite for the bluish white. For distinctly gray minerals, dark colored sphalerite may be used, if necessary.

The comparison may be made in several ways. The essential principle is to get the two objects to be compared as close together as possible in the field of vision. The following method has been used in this work and found to be very satisfactory. Each of the color standards is so ground that one side of the polished surface is bounded by a straight line; the specimen to be compared is similarly prepared and is mounted, together with the standard, so that the straight edges of the two are in contact and the two

polished surfaces are in the same plane, and can be directly compared under the microscope. (See Fig. 6.) Exceedingly delicate comparisons of color may be made in this way, and usually it is easy to prepare the specimen, though in the case of small grains included in other minerals the specimen has to be cut down care-

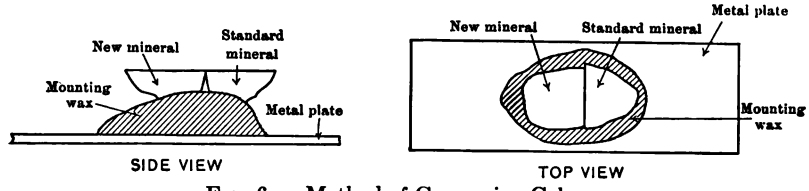


FIG. 6. — Method of Comparing Colors.

fully until an area of the mineral in question is at the straight edge. Another method employs a comparison eyepiece, which projects the images from two separate objects into one eyepiece, so that one-half the field is occupied by the image of one object and the other half by that of the other. This has the advantage that a small area in the middle of a specimen may be easily and quickly compared with the standard.

The beginner in this work may at the very outset experience some difficulty in this matter of color determination, but it has been found that the ability to distinguish minute differences in color grows very rapidly with experience, and it is astonishing how much more can be seen after a week's work than at the start.

As stated above, these determinations are comparative, with an arbitrary standard, because the eye is not accurate enough to carry such slight differences. Moreover, except in the case of the distinctly colored minerals, the differences are so slight that even spectroscopic measurements of the reflected wave length would probably be ineffective. The books on colors and color standards deal with far brighter colors than most of the tinted white minerals show. Ridgway's book on " Color Standards and Nomenclature,"[34] giving 1100 named colors, is the best and latest of its sort. He gives colored plates reproducing the shades and tints of the spectrum colors, with a white blank for comparison with the lightest tint of each color. Unfortunately, except for the distinctly colored and gray minerals, which are relatively few in number, all the sulphide minerals have colors falling somewhere between pure white and his lightest tint, usually much

nearer the white end, so his standards are of little use in this connection.

HARDNESS DETERMINATION

Hardness is often indicated by the character of the polish which a mineral will take. Very hard minerals may be either shiny and very much pitted, like magnetite, or dull and scratched, like pyrite. Medium minerals are smooth, or somewhat pitted, according to their brittleness. These can usually be smoothed off rather easily. Enargite is often considerably pitted, especially with insufficient polishing. Soft minerals practically always have a smooth, unpitted surface, but they are usually very easily scratched. An exception is galena, which usually shows triangular pits, not removed by later polishing, where fragments have been torn out along the cubic cleavage by the coarse grinding. Ordinarily even minerals with perfect cleavage give no indication of this on the polished surface.

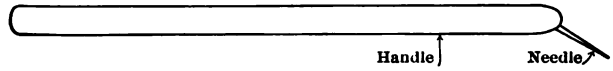


FIG. 7. — Needle Mounted for Testing Hardness.

For determining the hardness of opaque minerals on the polished surface, it is convenient to use a fine needle (No. 10 Sharp), mounted at an angle of about 30° to a $\frac{1}{4}$-ounce handle, 5 inches long. (See Fig. 7.) The idea is to have weight enough in the handle, when held near the middle, to cause the needle point to scratch soft minerals without additional pressure of the hand. This may be handled directly under the microscope, so that very small areas may be tested easily.

Careful investigation with specially designed apparatus permitting accurate determination of the hardness of minerals on the polished section indicates that many minerals possess distinctly different hardness in different crystal directions, so that two random sections of the same mineral in a polished section might give discordant results on accurate measurement, and lead to the erroneous supposition that two different minerals were present. On this account, it has not been considered advisable in this work to carry this determination of hardness too far, lest confusion arise from the overlapping of hardness ranges of various minerals. Accordingly, only three degrees of hardness are recognized: high, medium and low.

With oblique light, harder minerals in contact with softer ones show a bright rim on the side of the harder mineral towards the direction of illumination (reversed, of course, in the field of view of the microscope). With the prism illuminator this effect is most delicately observed when the area under observation is close to the edge of the field of view nearest the observer. This is the best method of determining the relative hardness of minerals.

MICROCHEMICAL TESTS

Microchemical tests are the most important of the means of classification, and in most cases are absolutely necessary, owing to the fact that very many minerals have practically the same physical characteristics.

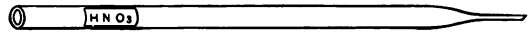


FIG. 8. — Pipette.

Method of Application. — The desired chemical reagent is best applied by means of a capillary pipette, so that a very small drop may be placed on the polished surface. This drop should be between 0.25 mm. and 2 or 3 mm., though in some cases it is allowable to use a larger drop, if the area of the mineral to be tested is considerable. The pipette may be made of small soft glass tubing drawn out to a fine point, so that the opening is about 0.25 mm. in diameter. It is convenient to have the tip of the pipette bevelled, to facilitate the flow of reagent when the instrument is touched in an inclined position to the specimen. (See Fig. 8.) The surface to be tested must be made absolutely clean by first rubbing on the rouge block, as any dirt or grease may not only render difficult the deposition of a drop of the reagent on the surface, but also may retard or prevent reaction which would otherwise take place, and so nullify the test. A separate pipette should be provided for each reagent and labelled appropriately. After using, the pipette should invariably be freed of excess reagent, either by washing or otherwise; failure to observe this precaution may lead to annoyance and even to erroneous results.

The application of the reagent may generally be best performed directly in the field of view of the microscope, so that any point may be selected and treated, thus permitting the testing of very small grains of a mineral surrounded by other opaque minerals or by gangue. (See Fig. 9.) This is important, as hybrid reactions are often obtained by etching mixtures of minerals, leading to

confusion in identification. This method of application of the reagent has the advantage that the very beginning of a reaction may be observed, and the result followed through to the end. This is very essential for some reactions, which start almost instantly, and would be too far advanced to observe if the specimen had to be taken from under the microscope, the reagent applied, and the specimen replaced for inspection of the effect. Moreover, instead of spoiling the whole specimen, only so much of the surface is etched as is desired, so that comparison may be made immediately of etched and unetched areas of a mineral.

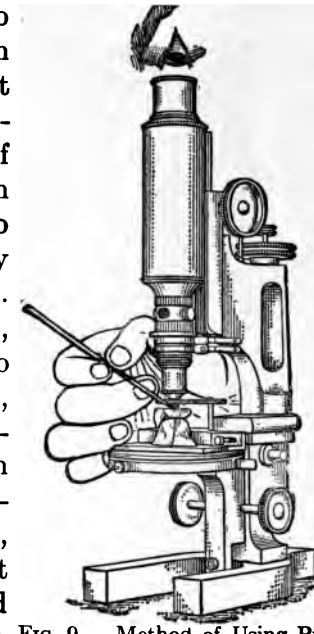


FIG. 9. — Method of Using Pipette (hardness may be tested in the same way, using the mounted needle. — See Fig. 7).

Reactions. — After the reagent is applied, a reaction is watched for. If there is no indication that any change is beginning, either in the mineral or reagent (except possibly that the latter evaporates rapidly), in about twenty seconds, the reaction is pronounced negative. If there is a reaction, its rate, and the changes both in reagent (coloration, evolution of gas, etc.) and mineral, must be carefully noted. Then without unmounting the specimen, the reagent is gently rinsed off with water or alcohol, and before rubbing, which would destroy any coating that had been formed, the specimen is examined again to observe the nature of the change, whether tarnish, or coating (black by vertical, and white or colored by oblique, light), or solution of the surface, shown by a roughening, with or without blackening. Sometimes etch-figures are developed. Some minerals are tarnished by acid fumes, while the acid itself leaves them apparently unchanged; this results in a halo of alteration surrounding the drop of reagent, but no evident attack on the area actually covered by the drop.

Then the specimen is dried off, rubbed on the rouge block and again examined, to determine whether the tarnish or coloration of the mineral is persistent, or whether it rubs off, leaving a clean surface with practically the original color of the mineral.

The different types and speeds of reaction are often very important in distinguishing minerals, several of which might be at-

tacked by the same reagent, but in different ways. It is therefore necessary to note carefully each feature of the reaction.

Some reactions are affected by the presence of other minerals. In testing very small areas, the drop of reagent necessarily overlaps onto the surrounding minerals, some of which may be affected. Calcite is particularly apt to obscure reactions with acid by neutralizing the reagent so quickly that it does not have time to make appreciable attack on the mineral for which it was intended. This possibility of interference of other minerals is the one perhaps most likely to cause erroneous results, but with the exercise of care in suspicious cases, difficulties may usually be avoided. In case of doubt, it is best, wherever possible, to find a grain of the mineral in question large enough entirely to hold a small drop of the reagent.

Reagents. — The following reagents have been used, to greater or less extent: the first eight have been found most useful. With further work, undoubtedly other reagents will be found to prove valuable in special cases. The symbols or abbreviations in the list below are the same as those used in the determinative tables of this book.

LIST OF REAGENTS

1. HNO_3 — Concentrated nitric acid diluted with equal volume of water.
2. HNO_3 conc. — Concentrated nitric acid. 70% (sp. gr. 1.42).
3. KCN — 20% solution.
4. HCl — Concentrated hydrochloric acid diluted with equal volume of water.
5. HCl conc. — Concentrated hydrochloric acid. 37% (sp. gr. 1.19).
6. Aq. Reg. — Freshly made Aqua Regia (3 HCl + HNO_3).
7. $FeCl_3$ — 20% solution.
8. KOH — Concentrated solution.
9. NaOH — Concentrated solution.
10. NH_4OH — 28% solution.
11. $(NH_4)_2S_x$.
12. Iodine — Solution in alcohol.
13. $K_3Fe(CN)_6$ — 20% solution.
14. $K_4Fe(CN)_6$ — 20% solution.
15. H_2SO_4 — dilute or concentrated.
16. $AgNO_3$ — 3% — 10% solution.
17. $KClO_3$ — Saturated solution, followed by conc. H_2SO_4.

The reagents are used cold, unless otherwise stated. Hot reagents are desirable in certain cases, though they usually have to be applied to the whole surface, thus making it necessary to re-polish the specimen for further examination.

MINERAL COMPOSITION AND IDENTITY

THE microscopic examination of polished surfaces is competent to detect mechanical mixtures of minerals, even when exceedingly minute. Moreover, it may be relied on to perceive even very slight color differences, due not to mechanical mixture, but to variation in chemical composition. Finally, specimens, which have been shown by crystallographic or other means to belong to the same species and which appear physically similar under the microscope, may show differences in microchemical behavior which must signify that the mineral in question is actually variable in chemical composition. It must be borne in mind, however, that color differences may also be caused by difference in perfection of polish; the variations due to actual differences in composition, however, are ordinarily exceedingly slight, while those due to imperfection of surface may be avoided by taking sufficient care in polishing, but with growing experience due allowance can be made for the effect produced on the true color by minute pits and scratches.

For purposes of discussion of composition and identity, minerals may conveniently be divided into a number of groups according to the prevailing view.

1. Minerals of thoroughly established identity and constant composition, such as pyrite or chalcopyrite.

2. Minerals of definitely established identity and variable composition, such as tetrahedrite or polybasite.

3. Minerals of fairly well established identity, supposed to be constant in composition, such as mohawkite.

4. Minerals described as definite species though believed by some to be mixtures, like cubanite.

With regard to these groups, mineralographic examination leads to the following conclusions.

1. The validity of this group is clearly established.

2. Some members of this group have been shown to owe their variable composition to the presence of other elements in chemical combination with the normal constituents of the mineral. This

variation in some cases does not appear to affect the physical or microchemical properties. Here, for example, belongs pyrrhotite, which has a variable amount of sulphur in excess of FeS, but which does not show any perceptible variation in properties and appearance under the microscope. Thus it appears that in the case of solid solutions, such as pyrrhotite has been shown to be, the variation may not appear in any way other than by a chemical analysis. In other cases there are small but perceptible differences, as in the case of polybasite, which shows by analysis a rather wide variation in composition, as regards the ratio of bases present.

The analyses of the tetrahedrite-tennantite series ($Cu_8Sb_2S_7$-$Cu_8As_2S_7$) are so variable that Hintze and Dana give different formulæ, and even then have to assume that various metals replace the copper to a greater or less extent. As a matter of fact, microscopic examination of many specimens shows that these minerals, even in good crystals, have a strong tendency to be intergrown with other sulphides, thus giving, in most of these instances, a simple explanation of the variation in composition shown by the analyses, and also accounting for many of the extra metals present. Pure material of this series shows but slight variation in color, the pure arsenic and pure antimony compounds being slightly though distinctly different, while the intermediate members of the series frequently cannot, without very close scrutiny, be distinguished from either end member. The copper may be in part replaced by silver, without change in color, though the microchemical properties are affected. It is quite probable that other metals may occur similarly, without changing the physical properties of the mineral.

Steinmannite, which is galena with chemically combined arsenic and antimony, exactly resembles galena in physical properties, but is somewhat different in microchemical behavior.

Many analyses of galena show the presence of other elements, such as arsenic, antimony, silver and sometimes bismuth, which the microscope has shown to be chemically combined with it, and which change only the microchemical properties. Some so-called argentiferous galenas are found on microscopic examination to contain small amounts of distinct silver minerals, which account for the silver content in these cases.

The various cobalt and nickel arsenides (such as smaltite, skut-

terudite, chloanthite, etc.) occur in mixtures with all proportions of these various minerals, along with minerals not belonging to the series. The crystals appear to be zoned, and this structure is generally revealed by etching, if not visible before. It is also suggested by differences in solubilities that have been noted in previous chemical work on these minerals. Inclusions of minerals not of the series have a strong tendency to take the form of suspended droplets or blebs in the host, like an emulsion. It is accordingly not surprising that analyses, even of crystals, have given variable results, and consequently some of the formulæ assigned to these minerals are probably wrong.

Other members of the second group owe their supposed variation to mechanical admixture, such as bornite. Analyses of bornite have varied between wide limits, and though it has long been recognized that this variation is usually due to mechanically admixed chalcocite, it has been a great question whether bornite really is of constant composition or not. In 1905, Harrington[18] analyzed pure material from several localities, both massive and in crystals, and established the definite formula Cu_5FeS_4, which has since been generally accepted. Mineralographic study has shown that very rarely indeed is absolutely pure bornite found in amounts large enough to analyze, and that the usual impurity is chalcocite, either intergrown with it, or formed in it as the result of alteration, though chalcopyrite is not uncommon, and other sulphides also occur. A large area of especially pure massive bornite, subjected to a careful geometric analysis on the polished surface, revealed only about 0.3 per cent of impurity, quite uniformly distributed through the material and consisting of chalcocite, chalcopyrite, tetrahedrite and galena. Selected portions of this material were sent for analysis to Dr. E. T. Allen of the Geophysical Laboratory in Washington. Dr. Allen's results[1] agreed with Harrington's and also with determinations which he made on some of Harrington's material and on other specimens of pure bornite, thus positively confirming Harrington's formula for the mineral. Furthermore, mineralographic examination of polished surfaces of bornite from at least 30 different localities has revealed only an exceedingly slight variation in color, and practically none in microchemical behavior.

In the face of all this concordant testimony and of the fact, noted by Harrington and confirmed by mineralographic examina-

tion of bornite crystals from Butte, Montana, and Cornwall, England, that many crystals of this mineral are pure externally but contain much intermixed chalcocite or chalcopyrite in the interior, the conclusion by Kraus and Goldsberry[23] that bornite is of variable composition must be regarded with doubt, especially as it appears that, although they sought to establish the purity of their material by microscopic examination with reflected light, they unfortunately failed to examine the material actually analyzed. Rogers[36] has come to the conclusion that the variability of bornite is due to the solid solution of chalcocite in bornite, and considers that Kraus and Goldsberry have proved that bornite really is variable in composition.

This occurrence of an impure basal or central portion in crystallized material is found to be surprisingly common in most sulphides, and is a possible source of error which should be guarded against by selecting for analytical purposes only material that has been very carefully and thoroughly examined microscopically in several crystallographic directions.

3. Minerals of this group have been shown in many cases to be mechanical mixtures: mohawkite or schapbachite, for instance.

4. Some minerals of this group have been definitely shown to be mechanical mixtures, like cubanite, thus confirming the prevalent opinion about them.

Sphalerite very frequently occurs filled with an " emulsion " of minute blebs or crystals of chalcopyrite, often arranged along crystallographic directions in the sphalerite. These would not appear in the hand specimen, and probably would not be visible even in thin section, especially if, as is apt to be the case, the sphalerite were rich in iron, and, hence, very dark. This same " emulsion " structure occurs in much greater perfection with bornite in chalcocite. Here there are often beautiful patterns of bornite droplets in the chalcocite, along both straight and curved lines. The droplets are often elongated in one direction, adding to the variety of the pattern, and approaching the typical " eutectic " structure.

OBSERVED MIXTURES

The following supposed mineral species, some of which have been regarded with doubt by mineralogists, have been shown with more or less certainty by mineralographic study to be mixtures

of two or more minerals. Some of these constituents are known while some, mainly because of their minute size, are as yet unidentified and it is very probable that several of them are actually new species. Unknown constituents have been treated at the appropriate places in the determinative tables.

Algodonite. — A mixture, or intergrowth of two unknown constituents, one creamy, the other grayish. The gray is rather less in amount, on the average. Determined in two specimens.

Alloclasite. — Probably glaucodot, or a similar mineral, with blebs of bismuth (?) and a bluish gray, soft mineral, scattered through it. There is also native gold, but this was recognized in the analyses. Only one piece was polished, but the material is typical, and undoubtedly the finding is reliable. The specimen appears like an emulsion of the softer minerals in the glaucodot.

Animikite. — Only one small specimen studied, but appears to be a mixture of several minerals. Possibly the study of more material would establish its identity more fully.

Barnhardtite. — A mixture resulting from the alteration of chalcopyrite to covellite and chalcocite. This has previously been recognized as a probable mixture, and the present determination, made on a piece of the type material, confirms this conclusively.

Brogniardite. — Appears in some specimens labelled brogniardite to be a mixture of ruby silver, galena (?) and possibly miargyrite; other specimens show a distinct mineral close to argentiferous jamesonite. Very dubious.

Carrolite. — Probably linnæite with intergrown bornite and chalcopyrite. Differs only slightly from linnæite from Siegen, agrees with linnæite from Mine La Motte, Missouri, and is intimately intergrown with enough of the copper minerals to furnish the copper required by the formula ascribed to carrolite. This determination is not final, but is highly probable.

Chalcopyrrhotite. — Probably a mixture of chalcopyrite with pyrrhotite, and some chalmersite. This is not certain, but is highly probable.

Cubanite. — A mixture of pyrite or pyrrhotite with chalcopyrite. Four specimens, from different localities, were examined and none was homogeneous, so the conclusion that cubanite is not a definite mineral but a mixture is probably reliable.

Domeykite. — Three specimens have the same characteristics as algodonite. Another has mixture of cream and purple.

Harrisite. — A pseudomorph of chalcocite after galena.

Homichlin. — Chalcopyrite altering to limonite, with a little chalcocite. This was determined on a large piece from the type locality, and is surely reliable.

Keweenawite. — A mixture of smaltite, niccolite, and domeykite, with usually a little stromeyerite (?). Determined from two pieces, one identified by Kœnig himself as keweenawite, and is conclusive.

Klaprotholite. — Alteration product of an unknown creamy mineral (?) with bismuth (?) and covellite. This was determined on only one specimen and may not be reliable, though as the material came from the type locality, the validity of klaprotholite seems doubtful.

Kobellite. — Intergrowth of galena with a mineral like bismuthinite or stibnite. Also determined on only one piece, which may not have been representative.

Mohawkite. — Mixture of two unknown constituents, one creamy and one grayish, like those in algodonite, but with more of the gray, and the two (algodonite and mohawkite) may not be exactly the same, though they appear very similar.

Plenargyrite. — Mixture of two unknown components, one soft and bluish, the other harder and creamier.

Schapbachite. — Practically the same as plenargyrite, but with slightly different properties.

Smaltite. — The group of cobalt and nickel arsenides shows probable zoning of different members in any one crystal, so that analyses cannot be relied on to show the composition of individual species.

Tapalpaite. — A mixture of creamy and grayish unknown components (?) Perhaps the creamy part is the true mineral. One good specimen studied.

Temiskamite. — A mixture of maucherite and niccolite, with a little cobaltite. Determined from the type specimen, and surely reliable.

PROBABLE MIXTURES AND DOUBTFUL MINERALS

The following names have been ascribed to certain supposed mineral species which are regarded in the standard text-books as doubtful. None of these has been examined by the author, but the similarity of the evidence in many cases to that for supposed minerals which actually have been examined, tends to indicate that examination would confirm the suspicion, and ac-

cordingly they are tentatively placed under this heading, pending investigation. The probable nature of each is indicated after the name. → indicates "altering to" *or* "altered to." For meaning of abbreviations see p. 46.

Acanthite = Distorted argentite
Alisonite = gn → cv or cc
Antimon-luzonite = famatinite?
Arite = NiSb and NiAs (mixture)
Arsenotellurite – Te, As, C? ?
Barracannite – impure material
Beyrichite = impure polydymite
Blueite = py
Bolivianite – Ag, Sb, S?
Bolivite – impure material
Bravoite – impure material
Cantonite = bn → cv
Castillite = bn and Ag?
Clarite = en
Clayite – Pb, Cu, Sb, As, S (altn. prod.?)
Coolgardite – impure material
Corynite – Ni, (Sb As), S
Crucite = arsenopyrite → hematite
Cuproplumbite = gn → cc and cv
Daleminzite = Ag_2S (orth.)
Danaite = Cobaltif. arsenopyrite
Dimorphite – As_4S_3?
Ducktownite – impure material
Dürfeldtite – (Ag, Pb, Sb, S)?
Fieldite = impure td.
Folgerite = pentlandite
Grunauite = impure polydymite?
Guadalacazarite = Hgs and ZnS?
Gunnarite = pentlandite
Heazlewoodite = pentlandite
Histrixite – $Cu_5Fe_5Bi_{14}Sb_4S_{37}$ (mixture)?
Horbachite – $4\,Fe_2S_3 \cdot Ni_2S_3$ (mixture).
Huascolite = gn and sl?
Jaipurite – CoS?
Joseite = tetradymite?
Kaneite = Mn, As ? ?
Kilbrickenite = geocronite
Kroeberite – (not analyzed)
Lautite = en and As
Ledouxite – impure material
Leviglianite – Ag_2S orth. and Fe?
Marrite – (not analyzed)
Metastibnite – Sb_2S_3 (amorphous)?
Müllerine = impure krennerite
Nepaulite = td
Orileyite = impure domeykite?
Osbornite – Ca, Ti?, S, O (meteoric)
Pacite = impure arsenopyrite?
Plumbomanganite – (MnPb), S?
Plumbostannite – Pb, Sn, Sb, S?
Quirogite = impure galena
Silaonite – impure material
Silverphyllinglanz = nagyagite?
Sommarugaite = Aurif. gersdorffite
Tombazite = py
Valeriite – Cu, Fe, Al, Mn_2, H_2, O, S? ?
Warrenite = jamesonite and zinkenite
Wehrlite – Bi, Te, S, Ag?
Whartonite = pyrite
Wolfachite – near corynite
Youngite – Pb, Zn, Fe, S, Mn?
Zorgite = clausthalite + umangite?

PLAN OF CLASSIFICATION

THE plan of classification in the tables that follow is based first of all on the *color* of polished minerals as seen under the microscope. The next test is relief or *hardness*. Subordinate to relief in part of the tables, *color* is again employed as a basis for subdivision. *Microchemical* tests come last.

COLOR

The opaque minerals are here divided into three main groups primarily by determination of color — that is, the color of the mineral as observed alone under the microscope, not compared with anything else. If the mineral has a decided color, it is called **colored.** If very pale colored, or white, it is classified as **white.** If distinctly **gray,** it is put under that heading.

Colored. — If a mineral has a distinct color, its identification is very simple, as there are comparatively few colored opaque minerals. Chalcopyrite, for instance, is yellow, covellite is blue, etc.

White. — If the mineral is white, or approximately so, the identification on the polished surface is more complicated, because a large majority of the sulphides fall in this class. It is, therefore, necessary to establish three subdivisions on the basis of hardness or relief. The subdivision with high relief needs no further color determination, except incidentally, but the other two, medium and low relief, are so extensive as to require still further subdivisions by color. This is made by color comparison with a standard, as described on page 26. It is exceedingly important that this step be made with care, because of the close similarity in appearance of many minerals. In fact, this is one of the most important and effective points in the classification, and without it the task of identifying a mineral in either of these groups would be tedious and difficult. With practice, the differences between the color subdivisions are easily recognized, the eye rapidly acquiring facility in detecting variations. To aid identification, in the case of minerals whose tints fall between two of the established groups, the mineral description in full is put in the group it appears to approach most closely and a reference to this is given in the appropriate place in the other group. Unfortunately, there are

a number of such minerals, but it is believed that with the full cross-referencing no trouble will arise from this source.

The secondary subdivisions by color, established by this comparison, are as follows:

Galena White. — This term has been used to denote the color of galena itself, and in this group are placed, in one subdivision, all minerals that appear pure white against galena, and in the other, all those the same color as galena, or only very slightly different.

Creamy White. — This is approximately the color of pure silver compared with galena, and in this group are placed all minerals appearing creamy white against galena. A division has been made of this group, using silver as a standard, into minerals paler than silver, or the same color, and minerals darker than silver.

Bluish White. — Minerals appearing bluish white against galena. Many of these are transparent.

Pinkish White. — Minerals appearing pinkish white against galena.

Grayish White. — Minerals appearing grayish white or grayish-greenish white against galena.

Other color values within the limits of white exist, but they are too indefinite for separate grouping and are noted by a qualifying adjective in the description of the mineral's color.

Gray. — If a mineral is distinctly gray, it may be compared with dark sphalerite, though this is not usually necessary, and may be used as a supplementary test. Some hard white minerals polish with difficulty, and often appear gray, because finely pitted.

Transparent and gangue minerals. — Some sulphides are transparent. This property may be detected by observing with oblique light, which may be obtained by temporarily stopping the aperture of the vertical illuminator. Transparent red minerals, like cuprite or ruby silver, reflect the complement of their transmitted color and appear bluish. All the transparent sulphides have a very high index of refraction, and probably for this reason appear bright on the polished surface by vertically reflected light. Sphalerite is the darkest of these and appears grayer than any other sulphide. Most gangue minerals are transparent, and practically all appear decidedly darker than sphalerite, which thus occupies an intermediate position. The transparent gangue minerals, usually with a fairly low index of refraction, appear dark gray because the light in large part penetrates the grain and is dispersed and lost on the irregular lower surface, while only a small portion is reflected back from the polished face.

Effect of surface on color. — Poorly polished surfaces appear darker than smooth ones, and pits on the polished surface appear black, because most of the light is scattered from the uneven bottom and sides. Minerals with high relief, surrounded by much softer ones, appear to be surrounded by a black rim, due to the sloping contact between the higher and lower mineral, which deflects the light obliquely.

HARDNESS

The second main division is based on *hardness*, as determined either by the actual relief of a mineral on the polished surface against a known constituent, by the character of the polish obtained, or by scratching directly under the microscope, with a fine needle point. By this means, three main groups are established, which are very satisfactory for rapid determination. Cross-referencing avoids error in cases of doubt as to the group in which a mineral actually falls.

1. **Hardness High.** — Minerals which are distinctly hard, stand up above most minerals, except quartz, and are scratched with difficulty, if at all, by the needle. Minerals from 4.5 to 5.5 in the scale of hardness can be grooved by a moderate pressure of the needle point, but do not show a typical scratch. Examples: pyrite, magnetite.

2. **Hardness Medium.** — Minerals which are not scratched by the weight of the handle alone, with no extra pressure applied, but are readily scratched by moderate pressure on the needle. Examples: chalcopyrite, enargite, tetrahedrite.

3. **Hardness Low.** — Minerals easily scratched by the weight of the handle alone. Examples: chalcocite, galena, bornite.

MICROCHEMICAL TESTS

The final determinative tests are microchemical, as in most cases a mineral cannot be identified by its physical properties alone. These separate the larger divisions into small groups in which any one mineral may be readily identified. The method of using these tests has already been described (p. 30).

EXPLANATION OF TABLES

Directions for Use. — The main divisions of the classification, **colored, white,** and **gray,** are indicated by the tabs of a thumb index at the top of the book. These are the only tabs on the *upper* margin

of the page, all others being on the *outer* margins. The first step in using the tables is to open them to the beginning of one of the main divisions, by holding down with the thumb the appropriate tab. This exposes the first subdivision, marked by a series of tabs on the *outer* margin of the *right hand* page. One of these tabs is then similarly held down, and the tables opened to the page carrying that tab, revealing the tabs of the second subdivision on the outer margin of the *left hand* page. This procedure is continued, the tabs alternating from right to left, until no more new sets appear, showing that the last subdivision has been reached. This is usually indicated by negative reactions on the left page and positive reactions on the right page; as, for instance, KCN *neg.* on the left and KCN on the right. (See pages 116–117.)

When this stage is reached, the full descriptions of the desired group of minerals will be found. A mineral name, followed by a reference to another page, indicates that the mineral does not properly belong in this group, but its full description may be looked up on the page indicated to make entirely sure in doubtful cases that it is not the mineral undergoing test. In running down a mineral, the tables must always be opened to the page which carries the tab for the test just made, and the next test to be applied is indicated by the tabs on the opposite margin as the book is held open.

Examples. — One or two examples will show clearly how the tables are intended to be used.

1. Suppose a mineral has been polished and inspected under the microscope. It appears *yellow;* therefore, hold down the **colored** tab and open to that page (p. 57). It is *yellow*, so hunt on the right hand margin for **yellow.** Place the thumb on this tab, and open to that page (p. 63). There are no tabs on the left, so the mineral in question must be found on the pages now open. The right hand page is headed **pale,** the left hand, **bright.** The mineral appears bright yellow, so it is sought on the left page, where are found chalcopyrite, gold, and yellowish and orange " bornite." Looking up the reference to yellowish and orange " bornite," one finds that these are not really bright yellow but always orange or brownish, so they may be eliminated. Under **Diff.** in the two minerals remaining, it is seen that they are distinguished from each other by color, behavior with KCN and character of surface. The chemical test is surest so KCN

is tried; it roughens and dissolves the surface of the yellow mineral, thus proving it to be gold.

2. Taking a white mineral this time, place the thumb on the **white** tab, open the book to that page (p. 81), and look on the right hand margin. Hardness appears to be the next test. The mineral appears smooth, and is easily scratched with a needle, showing it to have low hardness. Place the thumb on the tab **hardness low,** and open to that page (p. 143). Looking on the left hand margin, it is seen that the outer tabs refer to color, compared with galena, so the mineral is compared with galena and found to look faintly bluish. Place the left thumb on the tab marked **bluish white,** and open to the page carrying that tab (p. 114). Look on the right again. The next test is with HNO_3, so make that test, finding that the mineral is attacked by HNO_3, noting that it is plated almost instantly with a film that looks like metallic copper and that part of this film dissolves off quickly, and the mineral turns dark; in other words, HNO_3 gives a positive reaction, so hold down the HNO_3 tab and open to that page (p. 117). There are no more tabs on the left, so the final pages have been reached. The left says KCN *neg.*, the right says KCN, so test with KCN, finding that the mineral is rapidly etched and somewhat darkened. This puts it on the right hand side with a choice of cuprite, stromeyerite and chalcocite. The descriptions of these minerals indicate that chalcocite turns darker blue and effervesces with HNO_3, which rules it out; stromeyerite does not act with HNO_3 as the mineral in question has behaved, whereas cuprite fits the case exactly. A final assurance may be made by proving that the mineral is transparent red by oblique light, since chalcocite and stromeyerite are both opaque.

These directions have been made very explicit so that there shall be no chance for mechanical error in using the tables. To make sure no mistake or omission has occurred in running down a mineral, the sequence of tests identifying a given group is placed in the upper corner of the left hand page, so they all may be seen together, and checked up. By this means, the fewest possible tests need be applied, resulting often in a considerable saving of time. When the full description of the mineral is reached, other tests may, of course, be applied to check up the accuracy of the determination.

Cross-References. — As previously explained, numerous cross-references have been made in the case of minerals on the border

line between two or more colors or tints, or two classifications of relief, or with doubtful chemical behavior. That is, if a mineral might conceivably be called either *pale yellow*, or *cream colored*, or *white*, like pyrite, for example, its full description is placed under the heading *cream* and references to this are given in the proper place under each of the other two headings, so it can be found if the observer assigns it to any one of these colors. Similarly, a mineral like bournonite, which is intermediate in hardness between minerals of medium and of low relief, probably nearer medium, is fully described under *hardness medium*, and a reference given to this in the appropriate place under *hardness low*. The cross-referencing has been especially complete among the white and faintly tinted minerals, as here the color differences are very slight at best, and some intermediate tints are indefinite even to the practiced eye.

Abbreviations. — The abbreviations on the tabs are as follows: HNO_3 is taken as an example; abbreviations for other reagents may be found on page 32.

Abbreviation	Meaning
HNO_3. —	Attacked by HNO_3 (visibly changed or affected).
HNO_3 neg. —	Not attacked visibly by HNO_3.
Fumes HNO_3. —	Tarnished by the fumes of HNO_3 but not visibly attacked by the liquid, so that a ring of tarnish is formed around a clear spot, which was covered by the reagent.
Eff. HNO_3. —	Attacked by HNO_3, with effervescence.
No Eff. HNO_3. —	Attacked by HNO_3, but without effervescence.

In the descriptions of the minerals, the following abbreviations are used:

Col. — Color, including transparency.

Occ. — Habit of occurrence, if distinctive (such as platy, or in crystals or crystalline grains).

Hard. — Hardness.

Surf. — Character of polished surface.

H. — Hardness as given in Dana's System of Mineralogy; supplemented by comparison, where possible, with relative hardness to accompanying minerals.

Chem. — Microchemical tests.

Diff. — Distinctive characters, physical or chemical, which serve to distinguish a mineral from others of the group.

——. — Negative test.

The following abbreviations have been found convenient for designating some of the commoner sulphides:

py = pyrite	en = enargite
cp = chalcopyrite	sl = sphalerite
bn = bornite	gn = galena
cc = chalcocite	po = pyrrhotite
cv = covellite	mg = magnetite
td = tetrahedrite	G = gangue, including all the transparent, non-metallic minerals.

OUTLINE OF THE CLASSIFICATION

(Parentheses around a mineral indicate a cross reference, and that the full description is to be found elsewhere in the tables.)

1. **COLORED**
    1. BLUE
        1. BRIGHT
            1. Covellite
            2. (Chalcocite)
        2. PALE
            See: — WHITE — HARDNESS LOW — BLUISH WHITE.
    2. PURPLE
        1. BRIGHT
            1. Umangite
            2. Rickardite
            3. (Purplish brown "bornite")
        2. PALE
            1. (Purple "galena")
            2. (Coloradoite)
    3. YELLOW
        1. BRIGHT
            1. Chalcopyrite
            2. Gold
            3. (Orange "bornites")
        2. PALE
            1. HNO_3 NEG.
                1. Millerite
                2. (Pyrrhotite)
                3. (Sulvanite)
                4. (Chalmersite)
                5. (Gold, var. *electrum*)
            2. HNO_3
                1. (Marcasite)
                2. (Pyrite)
                3. (Bismuth)
    4. BROWN
        1. HNO_3 NEG.
            1. Orange "bornites"
            2. (Pyrrhotite)
            3. (Kalgoorlite)
        2. HNO_3
            1. Purplish brown "bornite"
            2. Sternbergite — Frieseite
            3. Bornite
            4. Unknown brown, Bisbee
            5. ("Bronze enargite")

5. PINK
1. HNO_3 NEG.
1. (Luzonite)
2. (Unknown pink — with mohawkite)
2. HNO_3
1. KCN NEG.
1. Niccolite
2. Breithauptite
3. (Maucherite)
4. (Bismuth)
2. KCN
1. Copper
2. (Bornite)
3. (Algodonite)
4. (Whitneyite)
5. (Cobaltite)
6. (Famatinite)

6. CREAM
1. HARDNESS HIGH
1. HNO_3 NEG.
1. Pyrrhotite.
2. Unknown pink — with mohawkite
2. HNO_3
1. SURFACE DULL
1. Pyrite
2. Marcasite
2. SURFACE SHINY
1. Linnæite
2. Maucherite
3. Hauchecornite
4. (Pentlandite)
5. (Niccolite)

2. HARDNESS MEDIUM
1. HNO_3 NEG.
1. Sulvanite
2. Chalmersite
3. (Millerite)
4. (Unknown, Butte, N 13)
5. (Pyrrhotite)
6. (Delafossite)
2. HNO_3
1. "Bronze enargite"
2. Algodonite (Cream)
3. Mohawkite (Cream)
4. Whitneyite
5. (Pentlandite)
6. (Aikinite)
7. (Niccolite)
8. (Linnæite)
9. (Copper)
10. (Hauchecornite)

3. HARDNESS LOW
See: — WHITE — HARDNESS LOW — CREAMY WHITE.

2. WHITE

1. HARDNESS HIGH
1. HNO NEG.
1. HCL CONC. NEG.
1. Rutile
2. Ilmenite
3. Hematite
4. (Pyrrhotite)
5. (Franklinite)

2. HCL CONC.
1. Magnetite
2. Sperrylite
3. (Unknown pink — with mohawkite)

2. NO EFF. HNO_3
1. HCL UNCHANGED
1. NO EFF. AQ. REG.
1. AQ. REG. NEG.
1. Cobaltite
2. (Linnæite)

2. AQ. REG.
1. Glaucodot
2. (Pentlandite)

2. EFF. AQ. REG.
1. $FeCl_3$ NEG.
1. Löllingite
2. Ullmannite
3. (Arsenopyrite)

2. $FeCl_3$
1. Chloanthite
2. Rammelsbergite

2. HCL TURNS YELLOWISH GREEN
1. Gersdorffite

3. EFF. HNO_3
1. AQ. REG. NEG.
1. (Pyrite)
2. (Marcasite)
3. (Argyropyrite)

2. AQ. REG.
1. $FeCl_3$ NEG.
1. Arsenopyrite
2. Kallilite
3. Willyamite
4. Polydymite

2. $FeCl_3$
1. Safflorite
2. Smaltite
3. Skutterudite
4. (Maucherite)

(103) 2. HARDNESS MEDIUM
(102) 1. GALENA WHITE
(102) 1. KOH NEG.
1. Chalcostibite
2. (Bournonite)
3. (Polybasite)
4. (Geocronite)
5. (Kallilite)

(103) 2. KOH
1. Berthierite
2. Guejarite

(100) 2. CREAMY WHITE
(100) 1. NO EFF. HNO_3
1. Pentlandite
2. (Sulvanite)
3. (Chalmersite)
4. ("Bronze Enargite")
5. (Berthierite)
6. (Linnæite)
7. (Hauchecornite)

(101) 2. EFF. HNO_3
1. Argyropyrite
2. Aikinite
3. (Domeykite)
4. (Algodonite, Cream)
5. (Mohawkite, Cream)
6. (Whitneyite)
7. (Kallilite)

(98) 3. PINKISH WHITE
(98) 1. HNO_3 NEG.
1. Luzonite
2. (Enargite)

(99) 2. HNO_3
1. Famatinite
2. (Argyropyrite)
3. (Geocronite)
4. (Breithauptite)

(92) 4. GRAYISH WHITE
(92) 1. HNO_3 NEG.
92 1. KCN NEG.
1. Bournonite
2. Tenorite
3. Delafossite
4. (Tetrahedrite)
5. (Regnolite)

(93) 2. KCN
1. (Polybasite)
2. (Enargite)
3. (Argyrodite)

2. FUMES HNO_3
1. KCN NEG.
1. Tetrahedrite
2. Tennantite
3. Hauerite
4. (Bournonite)

2. KCN
1. Enargite

3. HNO_3
1. KCN NEG.
1. Algodonite (Gray)
2. Polytelite
3. Alabandite
4 (Geocronite)
5. (Freibergite)
6. (Baumhauerite)
7. (Mohawkite gray)
8. (Crookesite)
9. (Plagionite)
10. (Stylotypite)
11. (Bournonite)

2. KCN
1. Mohawkite (gray)
2. Stylotypite
3. (Plagionite)

3. HARDNESS LOW
1. GALENA WHITE
1. PURE WHITE
1. HCL NEG.
1. Galenobismutite
2. Bismuthinite
3. Eucairite
4. Tellurium
5. Unknown (white), Bisbee
6. Lehrbachite
7. Berzelianite
8. Antimonial Bismuthinite
9. (Matildite)

2. HCL
1. Altaite
2. Clausthalite
3. Naumannite

2. SAME AS GALENA OR DARKER
1. HNO_3 NEG.
1. KOH NEG.
1. NO EFF. AQ. REG.
1. Jalpaite
2. Matildite
3. Unknown (Tonopah)

(14) 2. Eff. Aq. Reg.
1. Schirmerite
2. Rathite
3. Lengenbachite
4. Cinnabar
5. (Matildite)
6. (Polybasite)
7. (Bournonite)

(142) 2. KOH
1. Livingstonite
2. Stephanite
3. Sartorite
4. Dufrenoysite
5. (Berthierite)
6. (Miargyrite)

(132) 2. HNO_3

(132) 1. KCN Neg.

(134) 1. HCl Neg.

(134) 1. $FeCl_3$ Neg.

1. No eff. HNO_3
1. Nagyagite
2. Freieslebenite
3. Guitermannite
4. Beegerite
5. Jordanite?
6. Andorite
7. Epiboulangerite
8. Unknown (near Andorite)
9. (Bismuthinite)
10. (Lengenbachite)
11. (Baumhauerite)
12. (Jamesonite)

(135) 2. Eff. HNO_3
1. Boulangerite
2. Dognacskaite
3. Horsfordite
4. Plagionite
5. (Chiviatite)

(136) 2. $FeCl_3$
1. Arsenic
2. "Alloklas"
3. Rezbanyite
4. Plenargyrite (hard)
5. Schapbachite (hard)
6. Petzite

(132) 2. HCl

(132) 1. $FeCl_3$ Neg.
1. Geocronite
2. Meneghinite
3. Semseyite
4. (Zinkenite)
5. (Plagionite)
6. (Jamesonite)

(133) 2. $FeCl_3$
1. Lillianite
2. Galena
3. Steinmannite
4. Tetradymite?

(138) 2. KCN
1. Kermesite
2. Stibnite
3. Hessite
4. (Guejarite)
5. (Brogniardite)

(118) 2. CREAMY WHITE
(118) 1. SAME AS SILVER, OR WHITER
(120) 1. $FeCl_3$ NEG.
(120) 1. KOH NEG.
1. Matildite?
2. Guanajuatite
3. Chiviatite
4. (Bismuthinite)
5. (Galenobismutite)

(121) 2. KOH
1. Wittichenite

(118) 2. $FeCl_3$
(118) 1. NO EFF. AQ. REG.
1. Hessite?
2. Silver
3. (Altaite)

(119) 2. EFF. AQ. REG.
1. Huntilite

(122) 2. DARKER THAN SILVER
(126) 1. HNO_3 NEG.
1. Unknown (creamy, Butte)
2. (Sulvanite)
3. (Chalmersite)
4. (Berthierite)
5. (Gold, var. *electrum*)

(122) 2. HNO_3
(122) 1. $FeCl_3$ NEG.
1. Cosalite
2. Emplectite
3. Metacinnabarite
4. Sylvanite
5. (Frankeite)
6. (Wittichenite)
7. (Aikinite)
8. (Chiviatite)
9. (Freieslebenite)

(124) 2. $FeCl_2$

(124) 1. HCl Neg.

1. Melonite
2. Calaverite — (Krennerite)
3. Kalgoorlite
4. (Sylvanite)
5. (Arsenic)
6. (Hessite)
7. (Copper)
8. (Tapalpaite)
9. (Petzite)

(125) 2. HCl

1. Domeykite
2. Bismuth
3. Dyscrasite
4. Tapalpaite
5. Chilenite
6. (Teallite)

(114) 3. Bluish white.

(114) 1. HNO_3 Neg.

(114) 1. KOH Neg.

1. Tiemannite
2. Onofrite
3. Polyargyrite
4. Stützite
5. Unknown (Tonopah)
6. (Covellite)
7. (Kalgoorlite)
8. (Rathite)
9. (Cinnabar)

(115) 2. KOH

1. Proustite
2. Pyrargyrite
3. Unknown, bluish, with Sternbergite
4. Vrbaite
5. Miargyrite
6. (Stephanite)

(116) 2. HNO_3

(116) 1. KCN Neg.

1. Purple "galena"
2. Plenargyrite ("soft")
3. Schapbachite ("soft")
4. (Coloradoite)

(117) 2. KCN

1. Cuprite
2. Stromeyerite
3. (Chalcocite)
4. (Polyargyrite)
5. (Brogniardite)

4. GRAYISH WHITE

1. HNO_3 NEG.

1. KCN NEG.

1. Molybdenite
2. Regnolite
3. Seligmannite
4. "Argentiferous Jamesonite"
5. (Cinnabar)
6. (Kalgoorlite)
7. (Bournonite)
8. (Tiemannite)
9. (Rathite)
10. (Lengenbachite)

2. KCN

1. Orpiment
2. Argyrodite
3. Polybasite
4. Pearceite
5. (Jalpaite)
6. (Miargyrite)
7. (Stephanite)
8. (Livingstonite)

2. HNO_3

1. $FeCl_3$ NEG.

1. HCL NEG.

1. Stannite
2. Baumhauerite
3. Realgar
4. Crookesite
5. (Freieslebenite)
6. (Guanajuatite)
7. (Andorite)
8. (Unknown — near Andorite)

2. FUMES HCL

1. Cylindrite
2. Frankeite
3. Brogniardite
4. Jamesonite
5. Zinkenite

3. HCL

1. (Alabandite)
2. (Cosalite)

2. $FeCl_3$

1. KCN NEG.

1. Teallite
2. Aguilarite
3. Petzite?
4. Coloradoite

(107) 2. KCN
1. Chalcocite
2. "Tapalpaite" (gray)
3. (Unknown, Grayish, Butte, N 13)
4. Argentite
5. (Stromeyerite)
6. (Pearceite)

(145) 3. **GRAY**
(146) 1. HARDNESS HIGH
(146) 1. HCL CONC. NEG.
(146) 1. AQ. REG. NEG.
1. Cassiterite
2. Limonite
3. Chromite
4. (Rutile)
5. (Franklinite)
6. (Hematite)
7. (Ilmenite)

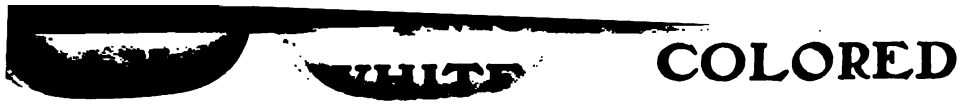
(147) 2. AQ. REG.
1. Uraninite

(144) 2. HCL CONC.
1. Franklinite
2. Psilomelane
3. (Magnetite)

(148) 2. HARDNESS MEDIUM
(148) 1. HCL NEG.
1. Sphalerite
2. Wurtzite
3. Voltzite
4. Erythrozincite
5. (Uraninite)
6. (Argyrodite)

(149) 2. HCL
1. Cuprodescloizite
2. (Cuprite)
3. (Alabandite)
4. (Tenorite)
5. (Delafossite)

(150) 3. HARDNESS LOW
1. Lorandite
2. (Stannite)
3. ("Petzite?")
4. (Argyrodite)
5. (Erythrozincite)
6. ("Tapalpaite" gray)



TABLES FOR MINERAL IDENTIFICATION

Bright

COVELLITE CuS

COL. Blue. Varies from deep bright blue, sometimes purple, to very pale blue, almost white, like chalcocite.

OCC. Usually in minute plates appearing as needles in section, sometimes even feathery aggregates. Rarely in large plates, up to two inches across.

HARD. Low. SURF. Smooth. H. 1.5–2 { > cc / = bornite

CHEM. 1. HNO_3 —. 2. HNO_3 conc. —. 3. **KCN.** Instantly deep violet, rapidly darker; rubs off, leaving a yellowish coating and rough surface. 4. **HCl** —. 5. **HCl conc.** —. 6. **Aq. Reg.** Instantly effervesces a short time, then stops; turns pinkish where bubbles started; rubs clean easily. 7. $FeCl_3$ —. 8. **KOH** —. 9. **NaOH** —. 10. $(NH_4)_2S_x$ —. 11. $AgNO_3$ 3 per cent —. Quickly plated with silver, persistent. 12. $K_4Fe(CN)_6$ —. 13. **Iodine** —. 14. $K_2Fe(CN)_6$. Slowly greenish, persistent. 15. NH_4OH —.

DIFF. *Col. Chem.* 1.

NOTE. Covellite, observed in plane polarised light, is pleochroic, dark blue (parallel to the plane of vibration of the nicol), to light blue (perpendicular to this). Sections which appear dark blue in ordinary light do not change color in polarised light.

CHALCOCITE See page 107.

Pale

See WHITE. HARDNESS LOW. BLUISH WHITE, pp. 114–117.
Many pale blue minerals are transparent red with oblique illumination.

Bright

UMANGITE Cu_3Se_2

COL. Bright reddish purple, very close to Rickardite.
HARD. Low. SURF. Smooth. **H. 3.**
CHEM. 1. HNO_3. Turns bluish, persistent. 2. **KCN**——. 3. **HCl.** Turns bluish, persistent. 4. **Aq. Reg.** Turns a little bluish; rubs to original color. 5. $FeCl_3$. Turns bluish, persistent. **6. KOH.** Slowly coated with brown; rubs easily to bluish. 7. $(NH_4)_2S_x$. Turns bluish; rubs to light blue.
DIFF. *Col. Chem.* 1.

RICKARDITE Cu_4Te_3

COL. Bright reddish purple, almost red, slightly brighter than umangite. Microscopically mottled, with bluish and yellowish patches mixed.
HARD. Low. SURF. Smooth. **H. 3.5.**
CHEM. 1. HNO_3. Instantly effervesces and blackens. **2. KCN.** Faintly bluish.
DIFF. *Col. Chem.* 1.

PURPLISH BROWN "BORNITE" See page 65.

Pale

PURPLE " GALENA " See page 116.

COLORADOITE See page 106.

COLORED
YELLOW

Bright

CHALCOPYRITE $CuFeS_2$

COL. Bright brass yellow. Sometimes appears pale, by association with colored minerals.
HARD. Medium. SURF. Smooth. H. 3.5–4 = bn.
CHEM. 1. HNO_3—. 2. HNO_3. Hot. Tarnishes the mineral bright colors, then dissolves it. 3. HNO_3 conc. Turns deep yellow; rubs off. 4. KCN— (but occasionally develops structure). 5. HCl—. 6. HCl conc.—. 7. HCl. Hot, same as hot HNO_3. 8. Aq. Reg. Tarnished iridescent. 9. $FeCl_3$—. 10. KOH—. 11. NaOH—. 12. $(NH_4)_2S_x$—. 13. $K_4Fe(CN)_6$—. 14. $K_3Fe(CN)_6$—. 15. Iodine—.
DIFF. *Col. Surf. Chem.* 4.

GOLD Au

COL. Golden yellow, richer than chalcopyrite, and usually deeper.
HARD. Low. SURF. Smooth, metallic. H. 2.5–3.
CHEM. 1. HNO_3—. 2. HNO_3 conc.—. 3. KCN. Quickly darkens and produces rough surface; sometimes develops structure. 4. HCl—. 5. HCl conc.—. 6. Aq. Reg.—. 7. $FeCl_3$. A little pale and tarnished (?); rubs off very easily. 8. KOH—. 9. NaOH—. 10. $(NH_4)_2S_x$—. 11. $K_4Fe(CN)_6$—. 12. $K_3Fe(CN)_6$—. 13. Iodine—.
DIFF. *Col. Surf. Chem.* 3.

NOTE. Gold is variable in color, according as it is alloyed with silver. Electrum is very pale yellow. A very good test for small pieces of gold is to amalgamate by rubbing on a mercury covered chamois skin. The gold will turn bright white. (F. C. Lincoln devised this test.)

YELLOWISH AND ORANGE "BORNITES" See page 64.

Pale

HNO_3 Neg

MILLERITE **NiS**

Col. Very pale yellow.
Hard. Medium. Surf. Smooth. H. 3–3.5 <po.
Chem. 1. **HNO_3**——. 2. **HNO_3** conc. Quickly bright yellowish brown; rubs off easily to very pale. 3. **KCN**——. 4. **HCl**——. 5. **HCl** conc.——. 6. **Aq. Reg.** Slowly bright brown; fumes tarnish brown; rubs clean easily. 7. **$FeCl_3$**——. 8. **KOH**——. 9. **NaOH**——. 10. **$(NH_4)_2S_x$**——. 11. **$K_4Fe(CN)_6$**——. 12. **$K_3Fe(CN)_6$**——. 13. **Iodine**——.
Diff. *Col. Chem.* 2, 6.

PYRRHOTITE See page 76.

SULVANITE See page 72.

CHALMERSITE See page 72.

GOLD (var. *electrum*) See page 62.

HNO_3

MARCASITE See page 78.

PYRITE See page 78.

BISMUTH See page 125.

COLORED
BROWN

HNO_3 Neg.

UNKNOWN MINERAL **"Orange Bornite"**

A group of unknown minerals, ranging in color from orange yellow to bright yellowish brown, occurring in small bits in bornite ores. Apparently not affected by HNO_3, but all reactions obscured by presence of easily soluble bornite. Usually resistant to enriching solutions.

PYRRHOTITE See page 76.

KALGOORLITE See page 124

UNKNOWN MINERAL **Purplish brown " Bornite "**

COL. Purplish brown. With bornite, distinctly purplish.
HARD. Low. SURF. Smooth. H = bn?
CHEM. 1. HNO_3. Dissolves readily with effervescence, leaving rough surface, pale gray or pinkish (more vigorous than ordinary bn).
DIFF. *Col. Chem.* 1.

NOTE. May be argentiferous bornite, as it occurs with silver minerals and native silver in the two specimens studied.

STERNBERGITE-FRIESEITE **$Ag_2Fe_5S_8$ or $AgFe_2S_3$**

COL. Pale yellowish brown. With bornite, pale yellowish brown, no pink.
HARD. Low. SURF. Smooth. H. 1–1.5.
CHEM. 1. HNO_3. Quickly bright iridescent; rubs to persistent gray. 2. KCN——. 3. HCl——. 4. Aq. Reg. Faint brown. 5. $FeCl_3$ ——. 6. KOH Quickly bright brown, rubs off.
DIFF. *Col. Chem.* 1, 2.

BORNITE **Cu_4FeS_4**

COL. Pinkish brown.
HARD. Low. SURF. Smooth. H. 3 < cp.
CHEM. 1. HNO_3. Quickly golden brown, with effervescence, occasionally developing "cleavage." 2. HNO_3 conc. Effervesces, tarnishes bright reddish brown, which rubs off, showing fine-grained "cleavage." 3. KCN. Quickly brown, developing "cleavage," like HNO_3. A more dilute sol. (3 per cent) produces coarser etching. 4. HCl——. 5. HCl conc.—— 6. Aq. Reg. Instantly effervesces and etches slightly; turns pale yellowish brown; fumes tarnish dark brown and iridescent. 7. $FeCl_3$——. Boiled with 5 per cent sol. a few minutes, etches better than KCN. 8. KOH——. 9. NaOH——. 10. $(NH_4)_2S_x$. Quickly blue and iridescent, rubs off easily. 11. H_2SO_4 conc.——. 12. NH_4OH——. 13. $K_3Fe(CN)_6$. Very bright, uniform brown, rubs off fairly easily. 14. $K_4Fe(CN)_6$ + HCl conc. Brilliant iridescent, persistent. 15. Iodine. Dissolves slightly.
DIFF. *Col. Chem.* 1.

NOTE. Color varies very slightly, from yellower to pinker brown.

UNKNOWN MINERAL **(Brown, from Bisbee)**

COL. Pale coffee brown. With bornite, pale grayish, yellowish, brown, no red; with sternbergite, faintly grayer brown, very close; with "orange bornite" slightly creamier brown, no red.
HARD. Medium or low. SURF. Smooth. H > bn. = cp.
CHEM. 1. HNO_3. Rather quickly tarnished slightly darker brown; rubs off easily. 2. KCN——. 3. HCl——. 4. Aq. Reg.—— (or slowly tarnished, with slight effervescence. Reaction may be modified by the presence of bornite). 5. $FeCl_3$——. 6. KOH——.
DIFF. *Col. Chem.* 1, 2.

BRONZE ENARGITE See page 74.

COLORED
PINK
HNO_3

KCN Reg.

NICCOLITE NiAs

COL. Creamy pink. With galena, distinctly pinkish cream; with maucherite, pale, decidedly yellowish brown; with copper, pale yellowish brown; with whitneyite, deep pinkish cream.
HARD. High. SURF. Shiny, pitted. H. 5–5.5.
CHEM. 1. HNO_3. Instantly effervesces, darkens and etches. Coated with white flocculent precipitate. Rubs off clean to show etched surface. 2. KCN—. 3. HCl—. 4. HCl conc.—. 5. Aq. Reg. Slowly brown, with moderate effervescence. 6. $FeCl_3$—. 7. KOH—. 8. NaOH—. 9. $(NH_4)_2S_x$—. 10. NH_4OH—. 11. $K_4Fe(CN)_6$—. 12. $K_3Fe(CN)_6$—. 13. Iodine—.
DIFF. *Col. Chem.* 1, 6.

NOTE. Niccolite with Sb shows intergrown breithauptite, or some other mineral, and does not appear to grade chemically into breithauptite.

BREITHAUPTITE NiSb

COL. Pink. With copper, very pale pink, no yellow tinge; with niccolite, pink, with no yellow tinge.
HARD. Medium. SURF. Smooth. H. 5.5 niccolite.
CHEM. 1. HNO_3. Quickly blackens and tarnishes; black persistent. 2. KCN—. 3. HCl—. 4. HCl conc.—. 5. Aq. Reg. Instantly effervesces, slowly turns brown and etches; rubs to persistent brilliant iridescent. 6. $FeCl_3$. Rapidly darkens; rubs clean, showing pitted surface. 7. KOH—. 8. $(NH_4)_2S_x$—. 9. NH_4OH—. 10. Iodine—. 11. $K_4Fe(CN)_6$—. 12. $K_3Fe(CN)_6$—.
DIFF. *Col. Chem.* 6.

MAUCHERITE See page 79.

BISMUTH See page 125.

HNO_3

KCN

COPPER **Cu**

COL. Pink. With bornite, bright pink; with breithauptite, decidedly yellowish pink.
HARD. Medium. SURF. Metallic, smooth. H. 2.5–3 > cc.
CHEM. 1. **HNO_3**. Dissolves rapidly, but merely roughens, and does not change color. 2. **HNO_3 conc.** Instantly dissolves, tarnishes bright iridescent, shows crystal (?) structure. Fumes tarnish iridescent, persistent. 3. **KCN**. Slowly tarnishes brown; rubs off to show very fine-grained solution surface. 4. **HCl**——. 5. **HCl conc.** Tarnishes slightly. 6. **Aq. Reg.** Blackens rapidly; rubs black and smooth. 7. **$FeCl_3$**. Instantly blackens and makes a solution pit. On washing off, the dilute solution tarnishes copper brilliant red, which rubs off. 8. **KOH**. Slowly tarnished bright brown, then red, then bright blue, persistent. 9. **$(NH_4)_2S_x$**. Instantly blackens, persistent. Fumes tarnish brilliant. 10. **NaOH**. Turns light reddish brown, persistent. 11. **Iodine**. Makes white coating, which rubs off very easily, showing roughened surface below.
DIFF. *Col. Surf.*

BORNITE See page 65.

ALGODONITE See page 74.

WHITNEYITE See page 75.

COBALTITE See page 86.

FAMATINITE See page 99.

COLORED
PINK
HNO_3 NEG.

LUZONITE See page 98.

UNKNOWN PINKISH MINERAL (in Mohawkite) See page 76.

HNO_3 NEG.

HNO_3

[redacted]

COLORED
CREAM
HARDNESS MEDIUM
HNO_3 NEG.

SULVANITE Cu_3VS_4

COL. Cream. With galena, very pale lemon yellow, almost cream; with silver, pale yellowish cream.
HARD. Medium. SURF. Smooth. H. 3.5.
CHEM. 1. HNO_3—. Fumes tarnish; rubs clean easily. 2. KCN—. 3. HCl—. 4. Aq. Reg. Tarnishes bright brown, rubs clean easily. 5. $FeCl_3$ —. 6. KOH—.
DIFF. *Col.*

CHALMERSITE $CuFe_2S_3$

COL. Cream. With galena, decidedly cream colored; with chalcopyrite, pale cream; with calaverite, decidedly yellower.
HARD. Medium. SURF. Smooth. H. 3.5 > cp.
CHEM. 1. HNO_3—. Fumes tarnish slightly. 2. KCN—. 3. HCl—. 4. Aq. Reg. Effervesces slightly; instantly bright iridescent, rubs clean easily. 5. $FeCl_3$ —. 6. KOH—.
DIFF. *Col.*

MILLERITE See page 63.

UNKNOWN CREAMY MINERAL (Butte, N 13) See page 126.

PYRRHOTITE See page 76.

DELAFOSSITE See page 92.

HNO; Neg

COLORED
CREAM
HARDNESS MEDIUM
HNO_3

BRONZE ENARGITE $CuSa$, $SbAs)_3S$?

COL. Cream. With pyrrhotite, same; with galena, pale brownish cream; with silver, pale brownish cream.
HARD. Medium. SURF. Smooth. H. = en.
CHEM. 1. HNO_3. Very slowly bright brown. 2. HNO_3 conc. Rather quickly brown, gradually turning lighter and iridescent. Rubs easily to very faint brown, often showing a little structure (?). 3. KCN. Solution slowly turns purplish red, increasing in intensity. Mineral is slightly etched but does not develop structure. 4. HCl—. 5. HCl conc.—. 6. Aq. Reg. Quickly bright brown iridescent; rubs clean easily. 7. $FeCl_3$—. 8. KOH—. 9. NaOH—. 10. NH_4OH—. 11. Iodine—. 12. $K_4Fe(CN)_6$—. 13. $K_3Fe(CN)_6$—.
DIFF. *Chem.* 3.

NOTE. Contains Cu, Sa, Sb, As, S. Probably analogous to enargite in composition, but with different crystal form.

ALGODONITE (CREAM) Cu_6As (?)

COL. Cream. With galena, pale pinkish cream; with whitneyite, pale cream; with mohawkite, cream; same.
HARD. Medium. SURF. Smooth. H. 4.
CHEM. 1. HNO_3. Instantly blackens with effervescence, leaving a rough surface. 2. KCN. Slowly brown, with slight effervescence. Rubs to pale gray and shows structure. 3. HCl—. 4. Aq. Reg. Effervesces slightly and darkens and etches. 5. $FeCl_3$. Instantly blackens. 6. KOH. Rapidly iridescent. 7. $(NH_4)_2S_x$. Instantly bright iridescent. 8. Iodine. Turns gray. 9. NH_4OH. Slowly pale, even, brown. 10. $K_4Fe(CN)_6$. Tarnished gray, rubs off. 11. $K_3Fe(CN)_6$. Faint brown, rubs off.
DIFF. *Chem.* 3, 6.

MOHAWKITE (CREAM) Cu_6As (with Ni and Co)

COL. Cream. With galena, pale pinkish cream; with algodonite (cream), same.
HARD. Medium. SURF. Smooth. H. 4.
CHEM. 1. HNO_3. At once black, with violent effervescence. 2. KCN. Dissolved and turned brown; rubs off pale. 3. HCl— (when with an unknown, harder mineral, blackens). 4. HCl conc. Same as 3. 5. Aq. Reg. Same as 3. 6. $FeCl_3$. Instantly blackens, develops structure (?). 7. KOH—. 8. $(NH_4)_2S_x$. Instantly yellow. 9. $K_3Fe(CN)_6$. Slowly brilliant persistent tarnish; dissolves visibly. 10. $K_4Fe(CN)_6$. Slowly faint tarnish, forming persistent ring. 11. Iodine. Turns bluish gray.
DIFF. *Col. Chem.* 3, 7.

NOTE. May be about the same as algodonite cream.

WHITNEYITE Cu_9As

COL. Cream. With galena, rather deep pinkish cream; with maucherite, pale brownish cream; with niccolite, cream; with copper, very pale yellowish brown.
HARD. Medium. SURF. Smooth, but apt to be finely pitted. H. 3.5.
CHEM. 1. HNO_3. Effervesces violently, and rapidly turns bright brown. Dissolved. 2. KCN. Quickly dark brown; rubs to gray, showing structure. 3. HCl. Tarnishes instantly; rubs clean. 4. Aq. Reg. Instantly blackens and dissolves; develops structure. 5. $FeCl_3$. Instantly blackens; rubs to dark gray. 6. KOH. Tarnishes quickly bright yellow, then brown. 7. NH_4OH. Slowly deep yellowish brown, rubs to very faint purplish tinge. 8. $(NH_4)_2S_x$. Instantly iridescent; rubs to dark gray. 9. $K_3Fe(CN)_6$. Instantly brown; rubs clean very easily. 10. $K_4Fe(CN)_6$. Faint brown, rubs clean. 11. Iodine, dark gray iridescent.
DIFF. *Col. Chem.* 3, 6.

HARDNESS MEDIUM

HARDNESS LOW

PENTLANDITE See page 100.

AIKINITE See page 101.

NICCOLITE See page 66.

LINNÆITE See page 79.

COPPER See page 67.

HAUCHECORNITE See page 79.

HNO.

COLORED
CREAM
HARDNESS MEDIUM
HNO_3

BRONZE ENARGITE (CuSn), (SbAs), S ?

COL. Cream. With pyrrhotite, same; with galena, pale brownish cream; with silver, pale brownish cream.
HARD. Medium. SURF. Shiny. H. = en.
CHEM. 1. HNO_3. Very slowly bright brown. 2. HNO_3 conc. Rather quickly brown, gradually turning brighter and iridescent. Rubs easily to very faint brown, often showing a little structure (?). 3. KCN. Solution slowly turns purplish red, increasing in intensity. Mineral is slightly etched, but does not develop structure. 4. HCl—. 5. HCl conc.—. 6. Aq. Reg. Quickly bright brown iridescent; rubs clean easily. 7. $FeCl_3$—. 8. KOH—. 9. NaOH—. 10. NH_4OH—. 11. Iodine—. 12. $K_4Fe(CN)_6$—. 13. $K_3Fe(CN)_6$—.
DIFF. *Chem.* 3.

NOTE. Contains Cu, Sn, Sb, As, S. Probably analogous to enargite in composition, but with different crystal form.

ALGODONITE (CREAM) Cu_6As (?)

COL. Cream. With galena, pale pinkish cream; with whitneyite, pale cream; with mohawkite (cream), same.
HARD. Medium. SURF. Smooth. H. 4.
CHEM. 1. HNO_3. Instantly blackens with effervescence, leaving a rough surface. 2. KCN. Slowly brown, with slight effervescence. Rubs to pale gray and shows structure. 3. HCl—. 4. Aq. Reg. Effervesces slightly and darkens and etches. 5. $FeCl_3$. Instantly blackens. 6. KOH. Rapidly iridescent. 7. $(NH_4)_2S_x$. Instantly bright iridescent. 8. Iodine. Turns gray. 9. NH_4OH. Slowly pale, even, brown. 10. $K_4Fe(CN)_6$. Tarnished gray, rubs off. 11. $K_3Fe(CN)_6$. Faint brown, rubs off.
DIFF. *Chem.* 3, 6.

MOHAWKITE (CREAM) Cu_3As (with Ni and Co)

COL. Cream. With galena, pale pinkish cream; with algodonite (cream), same.
HARD. Medium. SURF. Smooth. H. 4.
CHEM. 1. HNO_3. At once black, with violent effervescence. 2. KCN. Dissolved and turned brown; rubs off pale. 3. HCl— (when with an unknown, harder mineral, blackens). 4. HCl conc. Same as 3. 5. Aq. Reg. Same as 3. 6. $FeCl_3$. Instantly blackens, develops structure (?) 7. KOH—. 8. $(NH_4)_2S_x$. Instantly yellow. 9. $K_3Fe(CN)_6$. Slowly brilliant persistent tarnish; dissolves visibly. 10. $K_4Fe(CN)_6$. Slowly faint tarnish, forming persistent ring. 11. Iodine. Turns bluish gray.
DIFF. *Col. Chem.* 3, 7.

NOTE. May be about the same as algodonite cream.

WHITNEYITE Cu_9As

COL. Cream. With galena, rather deep pinkish cream; with maucherite, pale brownish cream; with niccolite, cream; with copper, very pale yellowish brown.
HARD. Medium. SURF. Smooth, but apt to be finely pitted. H. 3.5.
CHEM. 1. HNO_3. Effervesces violently, and rapidly turns bright brown. Dissolved. 2. KCN. Quickly dark brown; rubs to gray, showing structure. 3. HCl. Tarnishes instantly; rubs clean. 4. Aq. Reg. Instantly blackens and dissolves; develops structure. 5. $FeCl_3$. Instantly blackens; rubs to dark gray. 6. KOH. Tarnishes quickly bright yellow, then brown. 7. NH_4OH. Slowly deep yellowish brown, rubs to very faint purplish tinge. 8. $(NH_4)_2S_x$. Instantly iridescent; rubs to dark gray. 9. $K_3Fe(CN)_6$. Instantly brown; rubs clean very easily. 10. $K_4Fe(CN)_6$. Faint brown, rubs clean. 11. Iodine, dark gray iridescent.
DIFF. *Col. Chem.* 3, 6.

HARDNESS MEDIUM

HARDNESS LOW

PENTLANDITE See page 100.

AIKINITE See page 101.

NICCOLITE See page 66.

LINNÆITE See page 79.

COPPER See page 67.

HAUCHECORNITE See page 79.

COLORED
CREAM
HARDNESS MEDIUM
HNO_3

BRONZE ENARGITE **(CuSn), (SbAs), S ?**

COL. Cream. With pyrrhotite, same; with galena, pale brownish cream; with silver, pale brownish cream.
HARD. Medium. SURF. Shiny. H. = en.
CHEM. 1. **HNO_3.** Very slowly bright brown. 2. **HNO_3 conc.** Rather quickly brown, gradually turning brighter and iridescent. Rubs easily to very faint brown, often showing a little structure (?). 3. **KCN.** Solution slowly turns purplish red, increasing in intensity. Mineral is slightly etched, but does not develop structure. 4. **HCl**—. 5. **HCl conc.**—. 6. **Aq. Reg.** Quickly bright brown iridescent; rubs clean easily. 7. **$FeCl_3$**—. 8. **KOH**—. 9. **NaOH**—. 10. **NH_4OH**—. 11. **Iodine**—. 12. **$K_4Fe(CN)_6$**—. 13. **$K_3Fe(CN)_6$**—.
DIFF. *Chem.* 3.

NOTE. Contains **Cu, Sn, Sb, As, S.** Probably analogous to enargite in composition, but with different crystal form.

ALGODONITE (CREAM) **Cu_6As (?)**

COL. Cream. With galena, pale pinkish cream; with whitneyite, pale cream; with mohawkite (cream), same.
HARD. Medium. SURF. Smooth. H. 4.
CHEM. 1. **HNO_3.** Instantly blackens with effervescence, leaving a rough surface. 2. **KCN.** Slowly brown, with slight effervescence. Rubs to pale gray and shows structure. 3. **HCl**—. 4. **Aq. Reg.** Effervesces slightly and darkens and etches. 5. **$FeCl_3$.** Instantly blackens. 6. **KOH.** Rapidly iridescent. 7. **$(NH_4)_2S_x$.** Instantly bright iridescent. 8. **Iodine.** Turns gray. 9. **NH_4OH.** Slowly pale, even, brown. 10. **$K_4Fe(CN)_6$.** Tarnished gray, rubs off. 11. **$K_3Fe(CN)_6$.** Faint brown, rubs off.
DIFF. *Chem.* 3, 6.

MOHAWKITE (CREAM) **Cu_6As (with Ni and Co)**

COL. Cream. With galena, pale pinkish cream; with algodonite (cream), same.
HARD. Medium. SURF. Smooth. H. 4.
CHEM. 1. **HNO_3.** At once black, with violent effervescence. 2. **KCN.** Dissolved and turned brown; rubs off pale. 3. **HCl**— (when with an unknown, harder mineral, blackens). 4. **HCl conc.** Same as 3. 5. **Aq. Reg.** Same as 3. 6. **$FeCl_3$.** Instantly blackens, develops structure (?) 7. **KOH**—. 8. **$(NH_4)_2S_x$.** Instantly yellow. 9. **$K_3Fe(CN)_6$.** Slowly brilliant persistent tarnish; dissolves visibly. 10. **$K_4Fe(CN)_6$.** Slowly faint tarnish, forming persistent ring. 11. **Iodine.** Turns bluish gray.
DIFF. *Col. Chem.* 3, 7.

NOTE. May be about the same as algodonite cream.

WHITNEYITE **Cu_9As**

COL. Cream. With galena, rather deep pinkish cream; with maucherite, pale brownish cream; with niccolite, cream; with copper, very pale yellowish brown.
HARD. Medium. SURF. Smooth, but apt to be finely pitted. H. 3.5.
CHEM. 1. **HNO_3.** Effervesces violently, and rapidly turns bright brown. Dissolved. 2. **KCN.** Quickly dark brown; rubs to gray, showing structure. 3. **HCl.** Tarnishes instantly; rubs clean. 4. **Aq. Reg.** Instantly blackens and dissolves; develops structure. 5. **$FeCl_3$.** Instantly blackens; rubs to dark gray. 6. **KOH.** Tarnishes quickly bright yellow, then brown. 7. **NH_4OH.** Slowly deep yellowish brown, rubs to very faint purplish tinge. 8. **$(NH_4)_2S_x$.** Instantly iridescent; rubs to dark gray. 9. **$K_3Fe(CN)_6$.** Instantly brown; rubs clean very easily. 10. **$K_4Fe(CN)_6$.** Faint brown, rubs clean. 11. **Iodine,** dark gray iridescent.
DIFF. *Col. Chem.* 3, 6.

HARDNESS MEDIUM

HARDNESS LOW

PENTLANDITE See page 100.

AIKINITE See page 101.

NICCOLITE See page 66.

LINNÆITE See page 79.

COPPER See page 67.

HAUCHECORNITE See page 79.

HNO_3

COLORED
CREAM
HARDNESS HIGH
HNO_3 NEG.

PYRRHOTITE $FeS(S)_x$

COL. Cream. With galena, very pale brown; with silver, very pale brownish cream; with arsenopyrite, very pale creamy brown.
HARD. High. SURF. Shiny but pitted. H. 3.5–4.5 ≫ cp.
CHEM. 1. HNO_3—. Slowly very faint brown. Fumes tarnish slightly. 2. HNO_3 conc.—? 3. KCN—. 4. HCl—. Fumes quickly tarnish. 5. HCl conc.—. 6. Aq. Reg. Effervesces slowly, turns quickly brilliant iridescent in centre of drop, and brown near edges. Fumes instantly tarnish brown. Rubs off easily to pale brown. 7. $FeCl_3$—. 8. KOH. Slowly tarnishes brilliant iridescent colors, persistent. 9. NaOH, same as KOH. 10. $(NH_4)_2S_x$—. 11. $K_4Fe(CN)_6$—. 12. $K_3Fe(CN)_6$—. 13. Iodine—. 14. Hot HCl tarnishes quickly bright colors, different on different grains, then blackens and dissolves.
DIFF. *Col. Chem.* 6 and 14.

NOTE. Practically constant in color, though variable in sulphur content.

UNKNOWN MINERAL (pinkish, in Mohawkite) ?

COL. Pale pinkish cream. With galena, very pale brown or cream, with a tinge of pink; with maucherite, about same color.
HARD. High. SURF. Shiny, pitted. H. > mohawkite.
CHEM. 1. HNO_3—. Fumes tarnish slightly. 2. KCN—. 3. HCl—. 4. HCl conc.—. 5. Aq. Reg.—. 6. $FeCl_3$—. 7. KOH—.
DIFF. *Col. Chem.* 5.

NOTE. Some of the apparent inertness of this mineral may be due to the fact that it occurs surrounded by the readily attacked mohawkite, which may obscure or retard any reaction. Its presence certainly affects some of the reactions of the mohawkite.

The mineral may carry much Ni or Co, but this cannot be proved.

RAY WHITE

HNO₃ Neg.

HNO₃

COLORED
CREAM
HARDNESS HIGH
HNO_3

Surface Dull

PYRITE FeS_2

COL. Cream. With galena, pale creamy yellow; with arsenopyrite, pale yellow.
Occ. Rounded or irregular grains, or in crystals, practically always the oldest sulphide present.
HARD. High. SURF. Scratched and dull. H. 6–6.5.
CHEM. 1. HNO_3. Slowly faint brown, with very slow effervescence. Persistent. 2. HNO_3 conc. Same. 3. KCN——. 4. HCl——. 5. HCl conc.——. 6. Aq. Reg.——. 7. $FeCl_3$——. 8. KOH——. 9. NaOH—— 10. $K_4Fe(CN)_6$——. 11. $K_3Fe(CN)_6$——. 12. Iodine——. 13. $(NH_4)_2S_x$. Slightly tarnished ordinarily, but with enargite, rather brightly tarnished.
DIFF. *Hard. Occ. Col. Chem.* 1.

MARCASITE FeS_2

COL. Cream. With galena, pale creamy yellow; with silver, creamy white; with arsenopyrite, decidedly yellowish; with pyrite, slightly paler (usually); with millerite, paler and browner.
Occ. Frequently in radial growths, or intergrown with pyrite.
HARD. High. SURF. Scratched and dull. H. 6–6.5 = pyrite.
CHEM. 1. HNO_3. Slowly effervesces, and turns brown to black, slowly; persistent. 2. HNO_3 conc. Same. 3. KCN——. 4. HCl——. 5. HCl conc.——. 6. Aq. Reg. Very slowly faint brown, persistent. 7. $FeCl_3$——. 8. KOH——.
DIFF. *Col. Chem.* 1.

Surface Shiny

LINNÆITE CO_3S_4

COL. White. With galena, pale pinkish creamy white; with silver, very pale brownish cream; with arsenopyrite, very pale pinkish cream.
HARD. High. SURF. Shiny but usually pitted. H. 5.5 ≫ cp.
CHEM. 1. **HNO_3**. Very faintly brownish; fumes slowly tarnish brown. 2. **KCN**——. 3. **HCl**——. 4. **HCl conc.** Slowly very faint brown. 5. **Aq. Reg.**— Fumes tarnish slightly. 6. **$FeCl_3$**——. 7. **KOH**——. 8. **NH_4OH**——.
DIFF. *Col. Chem.* 1.

MAUCHERITE Ni_3As_2

COL. Cream. With galena, faintly pinkish cream; with silver, same as with galena; with niccolite, very pale gray; with whitneyite, pale grayish cream; with arsenopyrite, pale pink.
HARD. High. SURF. Shiny, pitted. H. 5.
CHEM. 1. **HNO_3**. Effervesces vigorously, and blackens almost immediately, rubbing clean to show roughened surface. 2. **KCN**——. 3. **HCl**——. 4. **HCl conc.**——. 5. **Aq. Reg.** Slowly brown, with moderate effervescence. 6. **$FeCl_3$**. Slowly faint brown, rather persistent. 7. **KOH**——. 8. **$(NH_4)_2S_x$**——. 9. **NH_4OH**——. 10. **$K_4Fe(CN)_6$**——. 11. **$K_3Fe(CN)_6$**. Pale brown iridescent tarnish, rubs off clean.
DIFF. *Col. Chem.* 1, 6.

HAUCHECORNITE $(NiCo)_7(Bi,S,Sb)_8$

COL. Cream. With galena, rich cream color; with pyrrhotite slightly less yellow, more of a pink tinge; polishes smoother, but is very close; with millerite, purplish gray.
HARD. High-medium. SURF. Smooth. H. = 5 ? > millerite.
CHEM. 1. **HNO_3**. Very slowly brown. Fumes tarnish slightly. Rubs clean easily, leaving a slightly etched surface. 2. **KCN**——. 3. **HCl**——. Fumes tarnish slightly. 4. **Aq. Reg.** Quickly turns bright brown, fumes tarnish slightly. Rubs clean very easily. 5. **$FeCl_3$**——. 6. **KOH**——.
DIFF. *Chem.* 4.

PENTLANDITE See page 100.

NICCOLITE See page 66.

HNO_3

WHITE
HARDNESS HIGH
EFF. HNO_3
AQ. REG. NEG.

ARGYROPYRITE See page 101.

MARCASITE See page 78

PYRITE See page 78.

EFF. HNO_3

Aq. Reg. Neg.

Aq. Reg

WHITE
HARDNESS HIGH
EFF. HNO_3
AQ. REG.

$FeCl_3$ Neg.

ARSENOPYRITE **FeAsS**

COL. White. With galena, pale cream; with silver, almost white, slightly creamy; with chloanthite, pale yellowish white.
HARD. High. SURF. Scratched and dull usually. H. 5.5–6 < py?
CHEM. 1. **HNO_3**. Quickly darkens (with effervescence) through iridescent colors to deep brown, with rough surface. 2. **KCN**——. 3. **HCl**——. 4. **HCl conc**——. 5. **Aq. Reg.** Slowly dark brown, with slight effervescence. 6. **$FeCl_3$** ——. 7. **KOH**——. 8. **NH_4OH**——.
DIFF. *Col. Chem.* 1, 6.

NOTE. Sometimes reaction 1 goes quite slowly. Gives off arsenic odor when ground on coarse wheel.

KALLILITE **NiBiS(Sb, As)**

COL. White. With galena, very pale creamy white.
HARD. High (medium). SURF. Smooth. H. > cp.
CHEM. 1. **HNO_3**. Quickly tarnishes iridescent. Effervesces slowly, darkens. Coated with white, some parts more than others. Rubs off to show gray, etched surface. 2. **KCN**——. 3. **HCl**——. 4. **Aq. Reg.** Instantly effervesces, turns slowly brown, darker where bubbles formed, and fumes tarnish brown instantly. Rubs clean, showing etched surface. 5. **$FeCl_3$**——. 6. **KOH**——.
DIFF. *Surf. Chem.* 1, 4.

NOTE. Very like willyamite, but softer?

WILLYAMITE **(CoNi)SbS**

COL. White. With galena, pale creamy white.
HARD. High. SURF. Shiny, pitted.
CHEM. 1. **HNO_3**. Instantly bright iridescent, then slowly dark brown. Slight effervescence. Coated with white. Rubs to gray etched surface. 2. **KCN**——. 3. **HCl**——. 4. **Aq. Reg.** Instantly effervesces, then slowly turns light brown, darker where bubbles formed. Rubs clean easily, leaving practically no trace of etching. 5. **$FeCl_3$**——. 6. **KOH**——.
DIFF. *Surf. Chem.* 1, 4.

NOTE. Very like kallilite, but harder?

POLYDYMITE **Ni_4S_5**

COL. White. With galena, pale creamy white; with arsenopyrite practically pure white; with rammelsbergite, very pale pink.
HARD. High. SURF. Shiny but pitted. H. 4.5 > cp.
CHEM. 1. **HNO_3**. Slowly bright iridescent with slow effervescence. Develops crystal structure. 2. **KCN**——. 3. **HCl** —— acid turns bright yellowish green. 4. **HCl conc.** Same as HCl. 5. **Aq. Reg.** Very slowly brown with slow effervescence. Acid turns greenish yellow. Fumes tarnish slightly. 6. **$FeCl_3$**——. 7. **KOH**——. 8. **NH_4OH**——.
DIFF. *Chem.* 1.

EFF. HNO_3

PENTLANDITE See page 100.

AIKINITE See page 101.

NICCOLITE See page 66.

LINNÆITE See page 79.

COPPER See page 67.

HAUCHECORNITE See page 79.

WHITE
HARDNESS HIGH
No EFF. HNO_3
HCl UNCHANGED
EFF. AQ. REG.

$FeCl_3$ Neg.

LÖLLINGITE **$FeAs_2$**

COL. White. With galena, very faint creamy white; with silver, practically pure white with a suggestion of pink; with arsenopyrite, same as with silver.
HARD. High. SURF. Shiny but pitted. H. 5–5.5 = py.
CHEM. 1. **HNO_3**. Very faintly brown, especially by fumes. 2. **KCN** ——. 3. **HCl**——. 4. **HCl conc.**——. 5. **Aq. Reg.** Slowly effervesces and very slowly turns faint brown, easily rubbed clean. 6. **$FeCl_3$**——. 7. **KOH**——. 8. **NaOH**——. 9. **$(NH_4)_2S_x$**. Slowly brown, dries iridescent brown; rubs clean easily. 10. **NH_4OH**——.
DIFF. *Chem.* 1, 6.
NOTE. Gives off arsenic smell when ground on coarse wheel.

ULLMANITE **NiSbS**

COL. White. With galena, white with very faint creamy tint; with arsenopyrite, practically pure white.
HARD. High. SURF. Shiny but pitted. H. 5.5–6.
CHEM. 1. **HNO_3**. Tarnishes quickly brown, then bright, repeating with higher order colors; rubs to persistent iridescent gray. 2. **KCN** ——. 3. **HCl**——. 4. **HCl conc.**——. 5. **Aq. Reg.** Effervesces strongly and blackens rapidly, effervescence stopping when black film forms. Rubs to persistent dull gray. 6. **$FeCl_3$**——. 7. **KOH**——. 8. **NH_4OH**——.
DIFF. *Chem.* 1, 6.

ARSENOPYRITE See page 82.

NO EFF. HNO_3

EFF. HNO_3

Eff. Aq. Reg.

$FeCl_3$

HCl Unchanged

CHLOANTHITE $NiAs_2$

COL. White. With arsenopyrite, pure white; with galena, faintly creamy white; with silver, pure white; with rammelsbergite, same color.
HARD. High. SURF. Shiny but pitted. H. 5.5–6.
CHEM. 1. HNO_3. Rather quickly brown, with tarnish around edges of drop; rubs to brownish gray, roughened surface. 2. KCN——. 3. HCl conc.——. 4. Aq. Reg. Effervesces and slowly darkens. Rubs faint. 5. $FeCl_3$. Mineral practically unchanged, but solution turns dark yellowish brown. 6. KOH——.
DIFF. *Chem.* 4, 5.

NOTE. Gives off arsenic odor when ground on coarse wheel.

HCl Turns Yellowish Green

RAMMELSBERGITE $NiAs_2$

COL. White. With galena, pale creamy white; with silver, practically pure white; with chloanthite, same; with arsenopyrite, white.
HARD. High. SURF. Shiny but often pitted. H. 5.5–6.
CHEM. 1. HNO_3. Rather quickly brown, with tarnish around the edges. Shows a roughened surface. 2. KCN——. 3. HCl——. 4. HCl conc.——. 5. Aq. Reg. Effervesces slowly and solution turns greenish yellow; shows roughened surface. 6. $FeCl_3$. Very slowly faint brown, persistent. 7. KOH——.
DIFF. *Chem.* 5, 6.

NOTE. Gives off arsenic odor when ground on coarse wheel.

WHITE
HARDNESS HIGH
No EFF. HNO_3
HCl UNCHANGED
No EFF. AQ. REG.

Aq. Reg. Neg.

No Eff. Aq. Reg.

COBALTITE **CoAsS**

COL. White. With galena, *pale* creamy brown; with silver, same as with galena; with arsenopyrite, pale pinkish brown.
HARD. High. SURF. Scratched and dull. H. 5.5–6 = py.
CHEM. 1. HNO_3. Very faintly browned, shows only after rubbing. 2. HCl——. 3. HCl conc.——. 4. KCN. Slowly very pale brown, rubs clean. 5. Aq. Reg.——. 6. $FeCl_3$——. 7. KOH——. 8. HN_4OH——.
DIFF. *Col. Chem.* 5.

LINNÆITE See page 79.

NO EFF. HNO_3

EFF. HNO_3

Eff. Aq. Reg.

GLAUCODOT **(CoFe)AsS**

COL. White. With galena, pale (brownish) creamy white; with silver, very pale brownish white; with arsenopyrite, very pale pinkish white. (Observed on a crystal face, not an artificially polished surface.)

HARD. High. SURF. Scratched and dull. H. 5.

CHEM. 1. HNO_3. Readily turns dark gray, producing rough surface. 2. KCN——. 3. HCl——. 4. HCl conc.——. 5. Aq. Reg. Very slowly tarnished dark brownish gray, persistent. 6. $FeCl_3$——. 7. KOH——. 8. Ammonium molybdate, 10 per cent——.

DIFF. *Col. Chem.* 1, 5.

NOTE. Gives off arsenic odor when ground on coarse wheel.

PENTLANDITE See page 100.

HCl Unchanged

HCl Turns Yellowish Green

WHITE
HARDNESS HIGH
No EFF. HNO_3
HCl TURNS YELLOWISH GREEN

GERSDORFFITE **NiAsS**

COL. White. With galena, faintly brownish creamy white; with arsenopyrite, practically pure white.
HARD. High. SURF. Shiny, but rough. H. 5.5.
CHEM. 1. HNO_3. Immediately tarnishes bright, then in a few seconds blackens; rubs to gray roughened surface. 2. KCN——. 3. HCl—— acid turns bright yellowish green. 4. HCl conc. Same as HCl. 5. Aq. Reg. Very slowly tarnishes brown, sometimes with effervescence; persistent. 6. $FeCl_3$——. 7. KOH——. 8. NH_4OH——. 9. Picric acid 10 per cent——.
DIFF. *Chem.* 1, 5.

NO EFF. HNO₃

EFF. HNO₃

HCl Turns Yellowish Green

WHITE
HARDNESS HIGH
HNO_3 NEG.

HNO₃ NEG.

HCl Conc. Neg.

RUTILE TiO_2

COL. White. With galena, pale grayish white; with tetrahedrite, very slightly grayer. Sometimes shows transparent red with oblique light, and is then bluer by vertical illumination.
HARD. High. SURF. Shiny, pitted. H. 6–6.5.
CHEM. Not attacked by any reagents.
DIFF. *Chem. Col.*

NOTE. Very hard to polish free from pits.

ILMENITE $FeTiO_3$

COL. White. With galena, pale grayish white; with sphalerite, distinctly whiter; with magnetite, pale purplish; with hematite, distinct pale purplish gray; with tetrahedrite, slightly grayer.
HARD. High. SURF. Shiny, pitted. H. 4.5–5 > magnetite.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl conc.—. 4. HCl conc. hot—. 5. Aq. Reg.—.
DIFF. *Col. Chem.*

NOTE. Very hard to polish free from pits. Sometimes shows slight variation in color. Frequently intergrown with magnetite.

NO EFF. HNO₃

HEMATITE Fe_2O_3

COL. White. With galena, pale creamy grayish white; with magnetite, white; with tetrahedrite, lighter, bluish? white.
OCC. Often as plates (specularite), and then easily recognised by form and hardness alone. Sometimes massive, intergrown with magnetite.
HARD. High. SURF. Shiny, pitted. H. 5.5–6.5 = mg.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl—. 4. HCl conc.—. 5. Aq. Reg.—. 6. $FeCl_3$—. 7. KOH—. 8. HCl conc. hot—. 9. HNO_3 hot—.
DIFF. *Col. Occ. Chem. Hard.*

NOTE. Very hard to polish free from pits.

PYRRHOTITE See page 76.

FRANKLINITE See page 144.

EFF. HNO₃

HCl Conc.

MAGNETITE Fe_3O_4

COL. White. With galena, very dull (purplish) grayish white; with sphalerite, distinctly lighter, with suggestion of creamy; with hematite, faint creamy brown; with ilmenite, lighter and creamy; with tetrahedrite, very pale grayish brown. Sometimes has a purplish tarnish, persistent.
HARD. High. SURF. Shiny, pitted. H. 5.5–6.5 < ilmenite and hematite.
CHEM. 1. HNO_3 conc.—. 2. KCN—. 3. HCl conc. slowly turns brown, some grains faster than others. Acid turns yellow. 4. Aq. Reg. Same as HCl conc. 5. HCl conc. hot. Readily blackened and dissolved.
DIFF. *Col. Chem.* 5.

NOTE. Very hard to polish free from pits.

SPERRYLITE $PtAs_2$

COL. White (not compared with any mineral, but appears white). The specimens examined were not polished, but were minute crystals, mounted in sealing wax, and the reactions observed on the crystal faces.
HARD. High. SURF. Shiny (would be pitted if polished). H. 6–7.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl—. 4. HCl conc. Very slowly faint yellow, washes off, leaving surface unchanged. Yellow probably due to coloration of acid. Test doubtful. 5. Aq. Reg. Same as HCl conc. but slower. 6. $FeCl_3$—. 7. KOH—. 8. $KClO_3$ and H_2SO_4 conc. Quickly bright orange yellow, then darker, to bright yellowish brown. Washes off to very pale brown, which rubs off easily. 9. H_2SO_4 conc. Slowly light brownish yellow, deepening gradually, easily washes off clean. Like $KClO_3$ and H_2SO_4 conc. but less vigorous.
DIFF. *Chem.* 8, 9.

UNKNOWN PINKISH MINERAL (in Mohawkite) See page 76.

WHITE
HARDNESS MEDIUM
GRAYISH WHITE
HNO_3 NEG.

KCN Neg.

BOURNONITE $(PbCu_2)_3Sb_2S_6$

COL. White. With galena, very pale grayish white, very nearly same; with silver, dull grayish (bluish) white; with tetrahedrite, grayish white, no brown.
HARD. Medium or low. SURF. Smooth. H. 2.5–3 < td.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl—. 4. HCl conc.—. 5. Aq. Reg. Quickly blackens with effervescence, produces a coating of free sulphur. 6. $FeCl_3$—. 7. KOH—. 8. NH_4OH—.
DIFF. *Chem.* 2, 5.

NOTE. Some bournonite is turned brown by HNO_3, acid and fumes, or by acid alone. Brighter along cracks in the mineral, or around pyrite grains.

TENORITE CuO

COL. White. With galena, pale greenish gray, and darker greenish gray (hard and soft portions); with tetrahedrite, hard part nearly the same, and soft decidedly darker. The soft part is probably the earthy form, melaconite.
OCC. Often crusted, like some limonite, with layers of varying hardness; or in minute plates or crystals.
HARD. Medium. SURF. Smooth. H. 3–4.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl. Quickly darkens; drop spreads out rapidly, forming and carrying with it a ring of pale greenish blue coating. Then acid rapidly evaporates, leaving a mass of minute acicular, nearly colorless crystals on the surface. Fumes tarnish brilliant iridescent. Fumes and coating wash off readily. 4. Aq. Reg. Same as HCl. 5. $FeCl_3$. Very slowly faint brown, rubs clean easily. 6. KOH—.
DIFF. *Chem.* 3.

DELAFOSSITE Cu, Fe, O

COL. Pale creamy gray. With galena, creamy gray; with sphalerite, grayish cream; with tetrahedrite, slightly yellower and duller.
HARD. Medium. SURF. Smooth. H. 2.5 > copper.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl. Darkens slightly and rather rapidly dissolves, developing structure. Shows etched surface clearly after rubbing. 4. Aq. Reg. Etches rather slowly and slightly. Acid quickly turns yellowish green. 5. $FeCl_3$—. 6. KOH—.
DIFF. *Col. Chem.* 3.

TETRAHEDRITE See page 94.

REGNOLITE See page 104.

KCN

HNO$_3$ Neg.

POLYBASITE See page 105.

ENARGITE See page 95.

ARGYRODITE See page 105.

Fumes HNO$_3$

HNO$_3$

WHITE
HARDNESS MEDIUM
GRAYISH WHITE
FUMES HNO_3

KCN Neg.

TETRAHEDRITE $Cu_3Sb_2S_7$

COL. Grayish white. With galena, dull pale gray with a suggestion of brown. Slightly variable, grading towards tennantite in color.
HARD. Medium. SURF. Smooth. H. 3–4.5 = cp.
CHEM. 1. HNO_3——. Fumes tarnish slowly light brown, rubs off easily (sometimes not affected even by fumes). 2. KCN—— (see note). 3. HCl——. 4. HCl conc. ——. 5. Aq. Reg. Slowly effervesces, acid turns greenish yellow; after a few minutes shows a coating of sulphur, which can be rubbed off, leaving a pitted surface. 6. $FeCl_3$——. 7. KOH——. 8. $(NH_4)_2S_x$. Slowly tarnished bright brown, rubs off. 9. $K_4Fe(CN)_6$——. 10. $K_3Fe(CN)_6$——.
DIFF. *Col. Chem.* 1, 5 (grades towards tennantite in properties).

NOTE. Freibergite, the silver bearing tetrahedrite, is very close to this, but is tarnished bright iridescent with HNO_3.
Mercurial tetrahedrite is *slightly* bluer, and is slowly tarnished bright iridescent with HNO_3. KCN left on for about a *minute and a half* turns ordinary tetrahedrite very faint brown, and etches it slightly.
Gives a reddish streak on the canvas wheel.

TENNANTITE $Cu_3As_2S_7$

COL. Grayish white. With galena, dull grayish, with a suggestion of green; with tetrahedrite, slightly bluer gray, grading towards the same color.
HARD. Medium. SURF. Smooth. H. 3–4.5 = cp.
CHEM. 1. HNO_3——. Fumes tarnish bright brown, rubs off. 2. KCN ——(see note). 3. HCl——. 4. HCl conc. ——. 5. Aq. Reg. Slowly effervesces, tarnishes bright iridescent in a few moments. Rubs off to show a pitted surface. 6. $FeCl_3$——. 7. KOH——. 8. $(NH_4)_2S_x$. Rather quickly bright brown. 9. $K_3Fe(CN)_6$. Slowly tarnished brown, rubs off. 10. $K_4Fe(CN)_6$——. 11. Iodine——.
DIFF. *Col. Chem.* 1, 5 (grades towards tetrahedrite in properties).

NOTE. With KCN for 1½ minutes acts same as tetrahedrite. Gives a reddish streak on the canvas wheel.

HAUERITE MnS_2

COL. Grayish white. With galena, pale gray or grayish white; with tetrahedrite, slightly white, or more neutral, with no yellowish tinge. Practically opaque.
HARD. Medium. SURF. Smooth. H. = 4.
CHEM. 1. HNO_3——. Fumes tarnish a little, very slowly. 2. KCN——. 3. HCl——. 4. Aq. Reg. Slowly very faint brown. Fumes tarnish faintly. Rubs clean easily, leaving a smooth surface. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 4.

NOTE. Gives an orange streak on the canvas wheel.

BOURNONITE See page 92.

ENARGITE Cu_3AsS_4

COL. White. With galena, very dull grayish white, with a suggestion of pinkish brown; with silver, very dull grayish white; with argentite, dull pinkish gray; with tetrahedrite, decidedly pinkish gray.

HARD. Medium. SURF. Smooth. H. 3 = cp.

CHEM. 1. HNO_3——. Fumes slowly tarnish faint brown. 2. **KCN**. Quickly blackens and etches. Rubs clean, showing etched surface with structure or cleavage developed. 3. **HCl**——. 4. **HCl conc.**——. 5. **Aq. Reg.** Quickly brown, appears to roughen; rubs clean easily. Fumes tarnish slightly. 6. $FeCl_3$——. 7. **KOH**——. 8. $(NH_4)_2S_x$. Slowly bright brown, iridescent; rubs clean easily. 9. $K_4Fe(CN)$. ——. 10. $K_4Fe(CN)_6$——. 11. **Iodine**——.

DIFF. *Chem.* 2, 5.

NOTE. Ordinary enargite, faintly pinkish, is here called white enargite. This shows perfect cleavage, and may be wholly pure Cu_3AsS_4, or, as in some cases, may carry considerable antimony without appreciably altering its physical or microchemical properties. (Some antimonial enargite from Peru, however, is browned and etched by HNO_3, while ordinary enargite is not.)

Massive white enargite, without cleavage, but in crystal grains, as shown by etching, has been observed from Goldfield. This carries equal portions of antimony and arsenic.

Pink enargite, which shows decidedly pink against ordinary enargite, has not been observed in crystals, except granular aggregates, without good crystal form, and never shows cleavage. It carries apparently all proportions between practically all arsenic and no antimony, to nearly all antimony and no arsenic. The former corresponds to luzonite, and the latter to famatinite. An intermediate member occurs in Goldfield, with about equal amounts of antimony and arsenic. This has slightly different microchemical properties from other pink enargites.

A whiter form of famatinite, with cleavage, that is, the antimony end-member of the normal enargite series, has not yet been observed.

Enargite is frequently intergrown curiously with tennantite, giving the former a mottled appearance. This is very common at Butte, and has been called "mottled enargite" by L. C. Graton and the writer. The enargite in this intergrowth is free from antimony, and also varies perceptibly in degree of pinkness.

Fumes HNO_3

HNO_3

WHITE
HARDNESS MEDIUM
GRAYISH WHITE
HNO_3

KCN Neg.

ALGODONITE (GRAY) **Cu_6As?**

COL. Grayish white (part of a mixture). With galena, very pale gray.
HARD. Medium. SURF. Smooth. H. 4?
CHEM. 1. **HNO_3**. Instantly blackens, with effervescence, leaving a rough surface. 2. **KCN**——. 3. **HCl**——. 4. **Aq. Reg.**——. 5. **$FeCl_3$**——. 6. **KOH**. Turns yellowish brown. 7. **$(NH_4)_2S_x$**. Instantly bright iridescent. 8. **Iodine**——. 9. **$K_4Fe(CN)_6$**. Blackened, rubs clean. 10. **$K_3Fe(CN)_6$**. Faint brown, rubs clean.
DIFF. *Chem.* 1, 4.

POLYTELITE **$4(PbAgFeZn)S{\cdot}Sb_2S_3$?**

COL. White. With galena, dull grayish white; with tetrahedrite, slightly grayer?
HARD. Medium. SURF. Smooth. H.? = Td?
CHEM. 1. **HNO_3**. Slowly bright brown and iridescent, persistent. 2. **KCN**——. 3. **HCl**——. 4. **Aq. Reg.** Instantly bright brown, effervesces and blackens, persistent. 5. **$FeCl_3$**——. 6. **KOH**——.
DIFF. *Chem.* 1, 2.

NOTE. Distinguished from freibergite only by the absence of copper. This is a very doubtful species.

ALABANDITE **MnS**

COL. Grayish white. With galena very pale dull gray; with silver, pale bluish gray; with argentite, slightly darker. Transparent *green* by oblique light.
HARD. Medium. SURF. Smooth. H. 3.5–4 = cp.
CHEM. 1. **HNO_3**. Instantly effervesces and darkens; rubs to light gray with little solution pits. If patch is large enough, odor of H_2S is evident. 2. **HNO_3 conc.** Same. 3. **KCN**——. 4. **HCl**. Same as **HNO_3**. 5. **HCl conc.** Same. 6. **Aq. Reg.** Dissolves readily with evolution of H_2S. Leaves a rather smooth solution pit. 7. **$FeCl_3$**——. 8. **KOH**——. 9. **NaOH**——. 10. **Iodine**. Brilliant tarnish; rubs off rather easily to faint. 11. **$(NH_4)_2S_x$**. Very slowly iridescent; rubs clean easily. 12. **NH_4OH**——. 13. **$K_3Fe(CN)_6$**. Slowly faint brown; rubs off easily. 14. **$K_4Fe(CN)_6$**. Same.
DIFF. *Col. Chem.* 1, 6.

GEOCRONITE See page 132.
FREIBERGITE See page 94 (note under tetrahedrite).
BAUMHAUERITE See page 108.
MOHAWKITE (GRAY) See page 97.
CROOKESITE See page 109.
PLAGIONITE See page 135.
STYLOTYPITE See page 97.
BOURNONITE See page 92.

UNKNOWN MINERAL (GRAYISH WHITE, Butte, N. 13)

COL. White. With galena, faint brownish grayish white; with silver, decidedly grayish white; with tetrahedrite, about same, but less yellowish, or brown (?).

HARD. Medium to low. SURF. Smooth. H. > bn < unknown creamy, Butte, N 13.

CHEM. 1. HNO_3. Instantly effervesces and turns gray, persistent. Develops cracks, rubs off rough. 2. **KCN**. Instantly brilliant iridescent. Rubs easily to pale, persistent tarnish. 3. **HCl**——. 4. **Aq. Reg.** Quickly darkens and roughens. Rubs fairly easily to original color. 5. $FeCl_3$. Rather quickly darkens, finally grayish brown; develops cracks; rubs off easily. 6. **KOH**——.

DIFF. *Chem.* 1, 2.

NOTE. Probably carries Bi.

MOHAWKITE (GRAY) Cu_3As **(with Ni and Co)?**

COL. Grayish white. With galena, very pale (yellowish ?) gray; with silver, same as with galena. Has needles of purplish color in it, like those in domeykite.

HARD. Medium. SURF. Smooth. H. 4.

CHEM. 1. HNO_3. Effervesces violently, turns purple, then black. 2. **KCN**——? (with unknown pinkish mineral, is slowly etched). 3. **HCl**—— (with unknown pinkish mineral is etched). 4. **Aq. Reg.**—— (with unknown pinkish mineral, is etched). 5. $FeCl_3$——. 6. **KOH**. Tarnishes bluish, rubs off, leaving purplish tinge. 7. **NaOH**. Tarnishes brown, then brilliant, persistent. 8. NH_4OH. Blackens, then turns iridescent. 9. $(NH_4)_2S_x$. Instantly iridescent. 10. $K_4Fe(CN)_6$. Slowly brilliant colors, very persistent. Forms solution pit.

DIFF. Occurrence as part of intergrowth. *Chem.* 6.

STYLOTYPITE $(Cu_2Ag_2Fe)_2Sb_2S_4$?

COL. White. With galena, grayish white; with tetrahedrite, practically the same.

HARD. Medium. SURF. Smooth. H. 3 = cp.

CHEM. 1. HNO_3. Very slowly brownish yellow and red. Some grains hardly touched. Fumes tarnish slightly. Rubs clean easily. 2. **KCN**. Turns faint gray? Rubs clean easily, leaving a slightly roughened surface. (Test is not well established.) 3. **HCl**——. 4. **Aq. Reg.** Slowly pale brown. After a while effervesces slightly. Fumes tarnish a little. Rubs clean easily. 5. $FeCl_3$——. 6. **KOH**. Very slowly faint brown. Rubs easily to very faint brown, slightly roughened surface.

DIFF. *Chem.* 1.

PLAGIONITE See page 135.

WHITE
HARDNESS MEDIUM
PINKISH WHITE

HNO_3 Neg.

LUZONITE Cu_3AsS_4

COL. Pink. With galena and silver, pale pink; with **enargite**, distinctly pale pink. Color variable faint to decided pink.
HARD. Medium. SURF. Smooth. H. 3.5 = en.
CHEM. 1. HNO_3——. Fumes tarnish slightly. 2. **KCN**. Slowly darkens and dissolves, like enargite, the darker pink more quickly than the paler. 3. **HCl**——. 4. **Aq. Reg.** Quickly bright iridescent, rubs off easily. 5. $FeCl_3$——. 6. **KOH**——.
DIFF. *Col. Chem.* 2.
See note under enargite, page 95.

ENARGITE See page 95.

PINKISH WHITE

HNO_3

FAMATINITE Cu_3SbS_4

COL. White. With galena, decidedly pinkish white; with enargite, distinctly pinkish white; with luzonite, about the same.
HARD. Medium. SURF. Smooth. H. 3.5.
CHEM. 1. **HNO_3**. Very slowly etched, turning brown, some parts more rapidly than others; at last iridescent. Fumes tarnish faintly. Rather persistent, shows etched surface. 2. **KCN**. Rather quickly brown, then iridescent, slowly, and is etched. Rubs to grayish brown, etched surface. 3. **HCl**——. 4. **Aq. Reg.** Rather quickly brown, slight effervescence. Fumes tarnish. Rubs clean quite easily. 5. **$FeCl_3$**——. 6. **KOH**——.
DIFF. *Col. Chem.* 1, 2.

NOTE. See note under enargite, page 95. A pink mineral from Goldfield, carrying equal parts of As and Sb, with the composition of an enargite, shows the following behavior: 1. **HNO_3** ——. Fumes tarnish faintly. 2. **KCN**. Very quickly dark brown, then black. Etches deeply.

ARGYROPYRITE See page 101.

GEOCRONITE See page 132.

BREITHAUPTITE See page 66.

WHITE
HARDNESS MEDIUM
CREAMY WHITE

No Eff. HNO_3

PENTLANDITE **(FeNi)S**

COL. Creamy white. With galena, very pale (creamy) yellow, not brown; with silver, about the same as with galena.
HARD. Medium. SURF. Shiny. H. 3.5–4 < po > cp.
CHEM. 1. **HNO_3**. Slowly light yellowish brown tarnish; rubs off. 2. **HNO_3 conc.** Slowly tarnishes bright yellow; rubs clean easily. 3. **KCN**——. 4. **HCl conc.**——. 5. **Aq. Reg.** Quickly bright brown, fumes slightly brown; rubs clean easily. 6. **$FeCl_3$**——. 7. **KOH**——. 8. **NaOH**——. 9. **$(NH_4)_2S_x$**——. 10. **H_2SO_4 conc.**——. 11. **$K_4Fe(CN)_6$**——. 12. **$K_3Fe(CN)_6$**——. 13. **Iodine**——.
DIFF. *Chem.* 1, 2.

SULVANITE See page 72.

CHALMERSITE See page 72.

BRONZE ENARGITE See page 74.

BERTHIERITE See page 103.

LINNÆITE See page 79.

HAUCHECORNITE See page 79.

ARGYROPYRITE **Ag, Fe, S and As?**

COL. White. With galena, pale creamy white; with silver, same as silver.
HARD. Medium. SURF. Smooth or slightly rough. H. 3.5–4 > arsenic.
CHEM. 1. HNO_3. Slowly blackens, with effervescence; rubs off to black and rough surface. 2. KCN——. 3. HCl——. 4. Aq. Reg.——. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 1.

NOTE. Intermediate between argentopyrite and sternbergite, in composition.

AIKINITE **$PbCuBiS_3$**

COL. White. With galena, pale creamy; with silver, very pale grayish white.
HARD. Medium or low. SURF. Smooth. H 2–2.5. > bn.
CHEM. 1. HNO_3. Effervesces and blackens, shows whitish coating (yellow and white mixed) on surface by oblique light. Fumes tarnish instantly iridescent then blacken. 2. KCN——. 3. HCl——. 4. HCl conc. Instantly dark brown, persistent. 5. Aq. Reg. Turns brown with slow effervescence, blackens. Rubs gray and rough. Shows slight white coating. Fumes tarnish instantly bright brown. 6. $FeCl_3$——. 7. KOH——.
DIFF. *Col. Chem.* 2.

DOMEYKITE See page 125.

ALGODONITE (CREAM) See page 74.

MOHAWKITE (CREAM) See page 74.

WHITNEYITE See page 75.

KALLILITE See page 82.

WHITE
HARDNESS MEDIUM
GALENA WHITE

KOH Neg.

CHALCOSTIBITE $CuSbS_2$

COL. White. With galena, very pale grayish white.
HARD. Medium. SURF. Smooth. H. 3–4.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl—. 4. Aq. Reg. Fumes instantly tarnish narrow rim bright. Acid slowly very faint brownish gray. Rubs clean easily. 5. $FeCl_3$—. 6. KOH—.
DIFF. *Chem.* 6.

BOURNONITE See page 92.

POLYBASITE See page 105.

GEOCRONITE See page 132.

KALLILITE See page 82.

BERTHIERITE $FeSb_2S_4$

COL. White. With galena, practically the same; with silver, like galena.
HARD. Medium. SURF. Smooth. H. 2–3.
CHEM. 1. HNO_3——. KCN——. 3. HCl conc.——. 4. Aq. Reg. Effervesces and turns slowly bright yellowish brown; fumes tarnish, rubs clean easily. 5. $FeCl_3$——. 6. KOH. Slowly bright brown. 7. NaOH Same as KOH, but more quickly.
DIFF. *Chem.* 1, 6.

GUEJARITE $Cu_3Sb_4S_7$

COL. White. With galena, nearly the same (faintly creamy). Shows two colors, grayer and whiter (probably due to orientation).
HARD. Medium. SURF. Smooth.
CHEM. 1. HNO_3. Quickly bright iridescent, then blackens. Rubs easily to gray, roughened surface. 2. KCN. Slowly faint brown. Rubs clean easily. 3. HCl——. 4. Aq. Reg. Slowly bright iridescent. Slowly effervesces. Rubs clean easily. 5. $FeCl_3$——. 6. KOH. Instantly iridescent, then blackened rapidly. Coated with yellow. Rubs off clean to show deeply dissolved and roughened surface.
DIFF. *Chem.* 6.

NOTE. Observations were made on minute crystals mounted in sealing wax, so that reactions may be somewhat affected.

WHITE
HARDNESS LOW
GRAYISH WHITE
HNO_3 NEG.

KCN Neg.

MOLYBDENITE MoS_2

COL. White. With galena, mixture of dull grayish white (with *purple* tinge), and white; with silver, mixture of dull purplish gray and white. Different colors due to different orientation?
HARD. Low. SURF. Smooth. H. 1–1.5 > cc.?
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl—. 4. Aq. Reg.—. 5. $FeCl_3$—. 6. KOH—. 7. NH_4OH—.
DIFF. *Col. Chem.* 1, 2, 4.

REGNOLITE $Cu_7As_2S_{12}$

COL. Grayish white. With galena, greenish grayish white; with tetrahedrite, pale greenish.
HARD. Low. SURF. Smooth. H. < Sl.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl—. 4. Aq. Reg. Rather slowly bright brown. Fumes tarnish faintly. Rubs clean easily. 5. $FeCl_3$—. 6. KOH—.
DIFF. *Chem.* 4.

SELIGMANNITE $CuPbAsS_3$

COL. White. With galena, grayish white; with tetrahedrite, very slightly lighter.
HARD. Low. SURF. Smooth. H. = 3.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl—. 4. Aq. Reg. Very quickly blackens with effervescence. Thinly coated with white. Rubs to rough gray surface. 5. $FeCl_3$—. 6. KOH. Rather slowly darkens to pale bluish iridescent. Rubs clean easily.
DIFF. *Chem.* 6.

NOTE. Practically the same as rathite in chemical properties.

ARGENTIFEROUS JAMESONITE (near Brogniardite)

COL. White. With galena, pale grayish white.
HARD. Low. SURF. Smooth. H. < cp.
CHEM. 1. HNO_3—. Fumes slowly faint brown. 2. KCN—? (or possibly very faint gray). 3. HCl—. 4. Aq. Reg. Effervesces slightly, and turns brown and iridescent. Fumes tarnish instantly. Rubs to faint gray, roughened surface. 5. $FeCl_3$—. 6. KOH—.
DIFF. *Chem.* 4.

NOTE. This mineral is distinctly browner than ordinary jamesonite, and does not agree in properties with any other mineral in this collection.

CINNABAR See page 141.
KALGOORLITE See page 124.
BOURNONITE See page 92.
TIEMANNITE See page 114.
RATHITE See page 141.
LENGENBACHITE See page 141.
UNKNOWN (Tonopah) See page 114.

HNO₃ Neg.

ORPIMENT As_2S_3

COL. White. With galena, pale grayish white; with proustite, pale (purplish) grayish white; with tetrahedrite, dull bluish gray; with cuprite, same as with proustite? Transparent yellow by oblique light.
HARD. Low. SURF. Smooth. H. 1.5–2.
CHEM. 1. **HNO_3**——. 2. **HNO_3 conc.**——. 3. **KCN.** Quickly dark, persistent. 4. **HCl conc.**——. 5. **Aq. Reg.** Fumes darken? 6. **$FeCl_3$**——. 7. **KOH.** Instantly blackens and dissolves. 8. **$(NH_4)_2S_x$.** Dissolves and forms rough surface. 9. **$K_4Fe(CN)_6$**——.
DIFF. *Col. Chem.* 3, 4.

ARGYRODITE Ag_8GeS_6

COL. White. With galena, dull grayish white; with tetrahedrite, very pale bluish gray, no brown.
HARD. Low. SURF. Smooth. H. 2.5.
CHEM. 1. **HNO_3**——. 2. **KCN.** Rather quickly brown, developing structure by differential attack. Rubs easily to a faintly etched surface. 3. **HCl**——. 4. **Aq. Reg.** Instantly iridescent; rubs bright iridescent, persistent. 5. **$FeCl_3$**——. 6. **KOH**——.
DIFF. *Chem.* 2, 4, 5.

POLYBASITE Ag_9SbS_6

COL. White. With galena, very pale grayish (greenish) white; with silver, bluish grayish white; with argentite, practically white; with tetrahedrite, grayish white, no brown. Color is slightly variable.
HARD. Low. SURF. Smooth. H. 2–3 = gn.
CHEM. 1. **HNO_3**——. 2. **KCN.** Rather quickly dark brown, then black; persistent, shows much roughened surface, sometimes with structure developed. 3. **HCl**——. 4. **HCl conc.** Fumes sometimes blacken, but this varies with different specimens, and some polybasite is not affected even by fumes. 5. **Aq. Reg.** Iridescent, with very slow effervescence, and not much tarnishing by fumes. Rubs clean, leaving a somewhat roughened surface, usually. 6. **$FeCl_3$**——. 7. **KOH**——. 8. **$(NH_4)_2S_x$.** Very slowly blackens, partially? This test is doubtful.
DIFF. *Chem.* 2, 5, 6.

PEARCEITE Ag_9AsS_6

COL. Grayish (greenish) white. With galena, very pale grayish green.
HARD. Low. SURF. Smooth. H. 3 = gn.
CHEM. 1. **HNO_3**——. Fumes tarnish; tarnish washes off. 2. **KCN.** Very quickly blackens and dissolves. Rubs to pale gray, rough surface. 3. **HCl**——. 4. **HCl conc.**——. 5. **Aq. Reg.** Instantly effervesces, turns iridescent, and darkens quickly. Rubs clean very easily. 6. **$FeCl_3$.** Quickly bright iridescent. Rubs clean easily. 7. **KOH**——.
DIFF. *Chem.* 6.

HNO₃

JALPAITE See page 140.
MIARGYRITE See page 115.
STEPHANITE See page 142.
LIVINGSTONITE See page 142.

WHITE
HARDNESS LOW
GRAYISH WHITE
HNO_3
$FeCl_3$

KCN Neg.

TEALLITE $PbSnS_2$

COL. White. With galena, creamy (?) grayish white; with tetrahedrite, slightly lighter.
HARD. Low. SURF. Smooth. H. 1–2.
CHEM. 1. **HNO_3.** Bright brown, then brilliant iridescent, some grains quickly, some more slowly. Rubs clean easily. 2. **KCN**——. 3. **HCl.** Slowly yellowish brown, fumes tarnish. Rubs clean easily. 4. **Aq. Reg.** Instantly iridescent, with effervescence; darkens, fumes tarnish. Rubs to gray, persistent. 5. **$FeCl_3$.** Slowly faint brown. 6. **KOH.** Slowly faint brown.
DIFF. *Chem.* 1, 3.

AGUILARITE $Ag_2S{\cdot}Ag_2Se$

COL. White. With galena, pale gray, with greenish tinge (?); with silver, dull pale grayish white.
HARD. Low. SURF. Smooth. H. 2.5 < cp.
CHEM. 1. **HNO_3.** Slowly tarnished brownish, rubs off very easily. 2. **KCN**——. 3. **HCl**——. 4. **HCl conc.**——. 5. **Aq. Reg.** ——? 6. **$FeCl_3$.** Slowly bright iridescent, rubs clean easily. 7. **KOH**——.
DIFF. *Chem.* 1, 3, 5.

(PETZITE ? unknown) ?

COL. White. With galena, purplish grayish white; with silver, decidedly purplish grayish white.
HARD. Low. SURF. Smooth. H. 2.5–3 < gold.
CHEM. 1. **HNO_3.** Instantly blackens, rubs to gray. 2. **KCN**——. 3. **HCl**——. 4. **Aq. Reg.** Instantly bright iridescent, rubs clean. 5. **$FeCl_3$.** Instantly iridescent; fairly persistent, dries bright. 6. **KOH**——.
DIFF. *Chem.* 1, 3, 4.

NOTE. Not true petzite, and usually with native gold. For petzite, see page 137.

COLORADOITE HgTe

COL. Grayish white. With galena, dull pale gray; with silver and tetrahedrite, same; same color as petzite (?).
HARD. Low. SURF. Smooth. H. 3.
CHEM. 1. **HNO_3.** Very slowly bright brown, then brilliant iridescent; rubs clean. 2. **KCN**——. 3. **HCl**——. 4. **Aq. Reg.** Slowly bright iridescent, with effervescence; rubs clean easily. 5. **$FeCl_3$.** Slowly faint brownish. Tarnished at edges of drop, rubs clean easily. 6. **KOH**——.
DIFF. *Chem.* 1, 3, 4, 5.

$FeCl_3$

GRAYISH WHITE

CHALCOCITE Cu_2S

COL. Grayish or bluish white. Sometimes "mottled," with bright colors, blue or green. With galena, pale bluish or grayish white; with silver, pale bluish white; with cuprite, slightly whiter.

HARD. Low. SURF. Smooth. H. 2.5–3 < bn.

CHEM. 1. **HNO_3**. Effervesces vigorously and etches, turning more or less blue. Develops cleavage or irregular cracking. 2. **HNO_3 conc.** Effervesces, turns blue, and dissolves, very rapidly, but does not develop cleavage. 3. **KCN**. Very rapidly blackens, rubs off to show cleavage or cracking, very fine grained. Dilute **KCN**. Produces coarser etching. 4. **HCl**. Changes color slightly and dissolves a little. 5. **HCl conc.** Same as **HCl**. 6. **Aq. Reg.** Dissolves readily, effervesces and develops cleavage, but changes color only slightly. 7. **$FeCl_3$**. Dissolves and turns slightly paler (?). Does not develop structure. 8. **KOH**—. 9. **NaOH**—. 10. **NH_4OH**—. 11. **$K_2Fe(CN)_6$**—. 12. **$K_4Fe(CN)_6$**. Slowly faint brown.

DIFF. *Col. Chem.* 1.

NOTE. Color variation of chalcocite is due partly to admixture of covellite in sub-microscopic fragments or solid solution. The reds and greens sometimes observed may not be due to this. "Mottled" chalcocite of this sort shows true chalcocite cleavage on etching.

CLEAVAGE. The writer has found by etching oriented sections of chalcocite crystals that this mineral possesses good cleavages parallel to the base and side pinacoid, and a poor one parallel to the front pinacoid. Therefore, no section will show more than two good cleavage directions, and will much more often show one good cleavage and one poor one. This affords a sure distinction between chalcocite which has its own crystal form, and chalcocite derived from bornite, which retains the structure of the bornite. In this case any section will show at least three directions of cleavage, of equal perfection though not necessarily equally abundant in development. These are octahedral directions. It has not been observed in unaltered bornite, but only when bornite is altering to chalcocite apparently under special conditions.

Anomalous cleavages have been noted in chalcocite crystals from certain localities, and these are not yet fully explained.

When in too small grains to show much cleavage, there is often a tendency for a single cleavage direction to be revealed, though the smaller areas do not show even this.

The hardness of chalcocite is slightly variable in different crystallographic directions.

UNKNOWN "TAPALPAITE" (GRAY) ?

COL. Grayish white. With galena, grayish white.

HARD. Low. SURF. Smooth.

CHEM. 1. **HNO_3**. Slowly iridescent, with effervescence, coated with white. Rubs clean. 2. **KCN**. Slowly darkens. Rubs clean. 3. **HCl**—. 4. **Aq. Reg.** Instantly effervesces and turns iridescent. Fumes tarnish iridescent. Rubs clean easily. 5. **$FeCl_3$**. Instantly iridescent, brilliant. Coated thinly with white? Rubs clean. 6. **KOH**—.

DIFF. *Chem.* 1.

ARGENTITE Ag_2S

COL. Grayish white. With galena, dull pale grayish white; with silver, same; with tetrahedrite, duller gray, no brown tinge; with enargite, very pale greenish, no pink tinge; with polybasite, very pale (greenish) gray; with stephanite, very pale greenish yellow; with dyscrasite, very dull gray.

HARD. Low. SURF. Smooth, but easily scratched. H. 2–2.5 < = gn.

CHEM. 1. **HNO_3**. Slowly light brown; fumes tarnish faintly; rubs off easily, and shows structure by differential etching. 2. **HNO_3 conc.** —. 3. **KCN**. Slowly or quickly dark brown, rubs off readily. Sometimes only faint brown, slowly. 4. **HCl**—. 5. **HCl conc.** Instantly tarnished iridescent by the fumes, and blackened by acid, forming a thick, persistent tarnish film. 6. **Aq. Reg.** Instantly iridescent. Fumes tarnish brighter than acid, persistent. 7. **$FeCl_3$** Slowly turns brown, dries iridescent; rubs off. 8. **KOH** —. 9. **NaOH**—. 10. **$(NH_4)_2S_x$**—.

DIFF. *Chem.* 3, 6, 7.

NOTE. With much galena, Aq. Reg. does not tarnish argentite so quickly or so much.

STROMEYERITE See page 117.

PEARCEITE See page 105.

WHITE
HARDNESS LOW
GRAYISH WHITE
HNO_3
$FeCl_3$ NEG.

HCl Neg.

$FeCl_3$ Neg.

STANNITE $SnCu_2FeS_4$ (Hintze)
[(Sn, Cu, Fe, Zn)S]

COL. Pale olive gray. With galena, pale yellowish brown, or greenish gray; with silver, pale dull brownish gray, or yellowish gray; with tetrahedrite, dull brownish gray. Color is apparently variable, from different localities.
HARD. Low. SURF. Smooth. H. 4 = cp.
CHEM. 1. HNO_3. Quickly brown, then brilliant iridescent; rubs off. 2. HNO_3 conc. Darkens quickly, then turns green, and effervesces, washes off black showing solution surface. Rubs clean, showing differential solution. 3. KCN——. HCl——. Fumes tarnish brownish. 4. HCl conc. Same as HCl. 5. Aq. Reg. Instantly effervesces and turns iridescent; develops grains; rubs clean easily. 6. $FeCl_3$ ——. 7. KOH——. 8. NaOH——. 9. $(NH_4)_2S_x$——. 10. NH_4OH ——. 11. $K_4Fe(CN)_6$. Slowly faint brown, dries darker, rubs off easily.
DIFF. *Chem.* 1, 7.

BAUMHAUERITE $Pb_4As_6S_{13}$

COL. White. With galena, pale grayish white; with tetrahedrite light grayish white, no brown.
HARD. Low. SURF. Smooth. H. 3.
CHEM. 1. HNO_3. Very slowly turns some portions light brown, others much less easily; rubs off easily. 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly iridescent, blackens with effervescence; rubs to persistent black. 5. $FeCl_3$——. 6. KOH. Quickly iridescent, with rapidly changing colors; rubs clean easily.
DIFF. *Chem.* 1, 6.

REALGAR AsS

COL. White. With galena, dull grayish white; with proustite, faintly purplish grayish white. Transparent orange by oblique light.
HARD. Low. SURF. Smooth. H. 1.5–2.
CHEM. 1. HNO_3. Effervesces but does not change color. 2. HNO_3 conc. Same. 3. KCN——. 4. HCl——. 5. Aq. Reg. Effervesces, turns brown and darkens, rubs to rough gray. 6. $FeCl_3$——. 7. KOH. Instantly brown, then blackens and dissolves very rapidly. 8. $(NH_4)_2S_x$——. 9. $K_4Fe(CN)_6$——.
DIFF. *Col. Chem.* 1, 7.

NOTE. Realgar with lorandite from Macedonia is transparent *red* by oblique light. Also is blackened, without effervescence, by HNO_3; and is *slowly* blackened by KOH.

$FeCl_3$

CROOKESITE $(CuTlAg)_2Se$

COL. Grayish white. With galena, grayish (brownish) white; with tetrahedrite, practically the same.
HARD. Low (medium). SURF. Smooth. H. = 2.5–3.
CHEM. 1. HNO_3. Slowly faint brown. Fumes instantly light brown. Rubs clean easily. 2. KCN——? (test not positive). 3. HCl——. 4. Aq. Reg.——. 5. $FeCl_3$——. 6. KOH——? (possibly *very* faint brown, doubtful).
DIFF. *Col. Chem.* 1.

GRAYISH WHITE

HCl Neg.

FREIESLEBENITE See page 134.

GUANAJUATITE See page 120.

ANDORITE See page 134.

UNKNOWN (near Andorite) See page 134.

Fumes HCl

HCl HNO_3

WHITE
HARDNESS LOW
GRAYISH WHITE
HNO_3
$FeCl_3$ NEG.

Fumes HCl

$FeCl_3$ Neg.

CYLINDRITE $3\,PbSnS_2 + SnFeSb_2S_6$

COL. White. With galena, pale grayish white; with tetrahedrite, almost the same, but no brown.
HARD. Low. SURF. Smooth. H. 2.5–3.
CHEM. 1. **HNO_3.** Slowly brown, then iridescent; rubs clean. Fumes tarnish slightly. 2. **KCN**——. 3. **HCl**——. Fumes tarnish pale brown. 4. **Aq. Reg.** Immediately brown, then iridescent; rubs clean easily. Fumes tarnish. 5. **$FeCl_3$**——. 6. **KOH.** Slowly brown, then iridescent; rubs clean easily.
DIFF. *Chem.* 1, 6.

FRANKEITE $3\,PbSnS_2 + Pb_2FeSb_2S_6$

COL. White. With galena, creamy grayish white; with silver, pale grayish white; with tetrahedrite, very close, but a little lighter.
HARD. Low. SURF. Smooth. H. 1–2.
CHEM. 1. **HNO_3.** Rather quickly brown, then brilliant iridescent; rubs clean easily. 2. **KCN**——. 3. **HCl**——. Fumes tarnish slightly. 4. **Aq. Reg.** Instantly iridescent, effervesces a moment; rubs clean easily. Fumes tarnish bright. 5. **$FeCl_3$**——. 6. **KOH.** Slowly pale brown, rubs clean.
DIFF. *Chem.* 1, 6.

BROGNIARDITE $PbAg_2Sb_2S_4$?

COL. White. With galena, pale (bluish) white; with tetrahedrite, distinctly bluish white.
HARD. Low. SURF. Smooth. H. = gn?
CHEM. 1. **HNO_3.** Slowly pale brown (differentially); rubs clean easily. 2. **KCN.** Slowly faint brown (uniform); rubs clean easily. 3. **HCl.** Very faint brown, slowly. Fumes tarnish light brown. Rubs clean easily. 4. **Aq. Reg.** Immediately effervesces and turns iridescent, darkening and developing a white coating. Fumes tarnish brilliant iridescent. Rubs to gray rough surface. Fumes rub clean. 5. **$FeCl_3$**——. 6. **KOH.** Instantly bright iridescent; rubs clean easily, showing etched surface.
DIFF. *Chem.* 1, 6.

NOTE. Close to jamesonite.

$FeCl_3$

JAMESONITE $Pb_2Sb_2S_6$

COL. White. Mixture of grayish and pale creamy whites, the gray decidedly harder. Act about the same chemically and appear to be differently oriented individuals. With galena, decidedly grayish creamy white, and almost same; with silver, same as with galena; with tetrahedrite, slightly grayer, and pure white.
HARD. Low. SURF. Smooth. H. 2–3.
CHEM. 1. **HNO_3.** Instantly brown, then black. White coating shown by oblique light. Rubs easily to brilliant iridescent, persistent. 2. **KCN**——. 3. **HCl**——. Fumes tarnish slowly bright; rubs easily to faint brown, persistent. 4. **Aq. Reg.** Rather quickly brown, with effervescence, then blackens. Gray quicker than white. Yellowish coating formed; rubs to gray rough surface. Fumes tarnish brilliant iridescent. 5. **$FeCl_3$**——. 6. **KOH.** Slowly blue and purple tarnish, white less touched, and some gray grains more than others.
DIFF. *Chem.* 1, 4, 6.

GRAYISH WHITE

ZINKENITE $PbSb_2S_4$

COL. White. With galena, pale grayish white; with tetrahedrite, lighter grayish white, no brown; with jamesonite, about same, may be a little bluer. Color slightly variable, due to different orientation of individuals.

HARD. Low. SURF. Smooth. H. 3+.

CHEM. 1. HNO_3. Quickly blackens with effervescence, rubs to iridescent gray, rough. 2. KCN——. 3. HCl——. Fumes slowly tarnish brown. 4. Aq. Reg. Instantly brown, then black; rubs to gray rough surface. Fumes tarnish instantly. 5. $FeCl_3$——. 6. KOH. Some grains instantly iridescent; some untouched. Rubs easily to pale colors.

DIFF. *Chem.* 1, 4, 6.

Fumes HCl

HCl

HNO_3

as Galena or darke

FeCl₂

FeCl₃ Neg.

WHITE
HARDNESS LOW
GRAYISH WHITE
HNO_3
$FeCl_3$ NEG.

HCl

ALABANDITE See page 96.

COSALITE See page 122.

HCl

HNO_3

as Galena or darke

WHITE
HARDNESS LOW
BLUISH WHITE
HNO_3 NEG.

KOH Neg.

TIEMANNITE **HgSe**

COL. White. With galena, distinctly pale blue; with silver, pale blue, darker than with galena.
HARD. Low. SURF. Smooth. H. 2.5.
CHEM. 1. HNO_3——. 2. HNO_3 conc.——. 3. **KCN**——. 4. **HCl**——. 5. **HCl conc.**——. 6. **Aq. Reg.** Rapidly blue, red, iridescent, then coated with orange yellow, rubbing to uniform gray. 7. $FeCl_3$——. 8. **KOH**——. 9. $(NH_4)_2S_x$. Very slowly brown, rubs clean. 10. NH_4OH——. 11. $K_4Fe(CN)_6$——. 12. $K_3Fe(CN)_6$——. 13. **Iodine.** Bright iridescent; rubs to persistent grayish green.
DIFF. *Chem.* 1, 6, 7.

ONOFRITE **Hg(SSe)**

COL. White. With galena, pale bluish white; with cuprite, bluish white, makes latter look creamy; with tiemannite, same. Shows intergrowth of whiter and browner portions, showing crystal outlines. May be due to different orientation.
HARD. Low. SURF. Smooth. H. 2.5.
CHEM. 1. HNO_3——. 2. **KCN.** Faintly blue and roughens. Rubs clean, showing shallow solution pit. 3. **HCl**——. 4. **Aq. Reg.** Quickly iridescent, growing brilliant; effervesces; finally coated with yellow. Rubs clean, showing deeply etched surface. 5. $FeCl_3$——. 6. **KOH**——.
DIFF. *Chem.* 2, 4, 5.

POLYARGYRITE **$Ag_{16}Sb_2S_{15}$**

COL. Bluish white. With galena, pale blue; with cuprite, bluish greenish gray, grayer than cuprite.
HARD. Very low. SURF. Smooth. H. 2.5 $\ll$ cp.
CHEM. 1. HNO_3——. Fumes tarnish. When with chalcopyrite, tarnishes slightly brown and iridescent. Rubs clean easily. 2. **KCN.** Instantly turns brown. Dries brilliant iridescent when rinsed off. Rubs clean rather easily. 3. **HCl**——. 4. **Aq. Reg.** Instantly brilliant iridescent, with effervescence. Fumes tarnish brilliant iridescent. Rubs clean easily. 5. $FeCl_3$. Rather quickly darkens and appears to roughen. Rinses off to brilliant iridescent. Rubs clean easily. 6. **KOH**——.
DIFF. *Chem.* 2, 5.

STÜTZITE **Ag_4Te ?**

COL. White. With galena, very pale bluish white.
HARD. Low. SURF. Smooth. H. = tellurium.
CHEM. 1. HNO_3——. 2. **KCN**——. 3. **HCl**——. 4. **Aq. Reg.** Effervesces and slowly turns bright iridescent then dark. Rubs easily to gray iridescent surface, roughened, and spotted with minute clean areas. 5. $FeCl_3$——. 6. **KOH**——.
DIFF. *Chem.* 4.

UNKNOWN (silver mineral, Tonopah, Nev.) ?

COL. Bluish white. With galena (grayish), bluish white; with silver, bluish white.
HARD. Low. SURF. Ragged. H < silver.
CHEM. 1. HNO_3——. Fumes tarnish slightly. 2. **KCN**——. 3. **HCl**——. 4. **HCl conc.**——. Fumes tarnish slightly. 5. **Aq. Reg.** Instantly brilliant iridescent. Fumes same, rubs clean easily. 6. $FeCl_3$. Slowly darkens and turns iridescent. Rubs clean easily. 7. **KOH**——.
DIFF. *Chem.* 2, 6.

NOTE. Same as polyargyrite except that it does not effervesce with Aq. Reg., and is not attacked by **KCN.**

COVELLITE See page 58.
KALGOORLITE See page 124.
RATHITE See page 141.
CINNABAR See page 141.

KOH

PROUSTITE Ag_3AsS_3

COL. Bluish white. With galena, bluish white; with cuprite, about the same. Transparent brilliant red with oblique light.
HARD. Low. SURF. Smooth. H. 2.5 = gn.
CHEM. 1. HNO_3——. 2. HNO_3 conc.——. 3. KCN. Slowly light brown, developing scratches. When rinsed off, without rubbing, shows little or no orange yellow coating, rubs clean easily. 4. HCl——. 5. HCl conc.——. 6. Aq. Reg. Brown, then iridescent, then effervesces slowly, and blackens. Rubs easily to persistent light brown. Fumes tarnish. 7. $FeCl_3$. Slowly faint tarnish? 8. KOH. Instantly brown, quickly darkening. Rubs to pale yellowish roughened surface. 9. NaOH. Same as KOH. 10. $(NH_4)_2S_x$. Slowly faint brown, rubs off clean. 11. NH_4OH——. 12. $K_4Fe(CN)_6$——. 13. $K_3Fe(CN)_6$——.
DIFF. *Col. Chem.* 3.

NOTE. The presence of some Sb probably accounts for any coating with KCN.

PYRARGYRITE Ag_3SbS_3

COL. Bluish white. With galena, pale bluish white; with proustite, slightly lighter? Transparent brilliant red by oblique light.
HARD. Low. SURF. Smooth. H. 2.5 = gn.
CHEM. 1. HNO_3——. 2. HNO_3 conc.——. 3. KCN. Slowly light brown, developing scratches. When rinsed off, shows orange yellow coating, rubs off, leaving solution pit. 4. HCl——. 5. HCl conc.——. 6. Aq. Reg. Brown, then iridescent, then effervesces slowly and blackens. Rubs easily to light brown, persistent. Fumes tarnish. 7. $FeCl_3$. Dissolves (?) slightly, but does not change color. 8. KOH. Instantly iridescent, and immediately blackens and dissolves. Rubs off to show solution pit colored pale brownish yellow. 9. NaOH. Same as KOH. 10. $(NH_4)_2S_x$. Slowly faint brown, rubs off clean. 11. NH_4OH——. 12. $K_4Fe(CN)_6$——. 13. $K_3Fe(CN)_6$——.
DIFF. *Col. Chem.* 3.

UNKNOWN (Bluish white, with sternbergite, from Joachimsthal)

COL. Bluish white. With galena, pale bluish white; with silver, decidedly bluish white.
HARD. Very low. SURF. Smooth. H. = cc.?
CHEM. 1. HNO_3——. 2. KCN. Darkens to gray, develops structure. 3. HCl——. 4. Aq. Reg. Black and iridescent, persistent. 5. KOH. Rapidly iridescent, then black. Rubs clean showing solution surface. 6. $FeCl_3$——.
DIFF. *Col. Chem.* 2, 4.

NOTE. Possibly near miargyrite.

VRBAITE $TlAs_2SbS_4$

COL. Bluish white. About like cuprite. Transparent red by oblique light.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3——. 2. KCN——. 3. HCl——. 4. Aq. Reg. Quickly effervesces and blackens. Rubs to gray, rough surface. 5. $FeCl_3$——. 6. KOH. Instantly iridescent. Rubs to persistent gray, roughened surface.
DIFF. *Chem.* 2.

MIARGYRITE $AgSbS_2$

COL. White. Faintly mottled, in various shades, like chalcocite. With galena, bluish white; with silver, bluish white. *Deep red transparent* with bright oblique light.
HARD. Low. SURF. Smooth. H. 2–2.5.
CHEM. 1. HNO_3——. 2. KCN. Slowly pale brown, rubs faint, persistent. 3. HCl——. 4. Aq. Reg. Quickly brown, with effervescence, then iridescence. Yellowish white coating formed. Rubs to gray, roughened surface. Fumes tarnish slowly, bright iridescent. 5. $FeCl_3$——. 6. KOH. Instantly iridescent, with rapid change of colors to higher orders, the last stage brownish gray and dark brown. Rubs to gray, rough surface, showing differential solution; white usually more resistent.
DIFF. *Col. Chem.* 2, 4.

STEPHANITE See page 142.

HNO_3 Neg.

HNO_3 as galena or garner

WHITE
HARDNESS LOW
BLUISH WHITE
HNO_3

KCN Neg

UNKNOWN "Purple Galena."

COL. Pale purplish gray. With galena or silver, pale purplish gray; with coloradoite, somewhat bluer.

HARD. Low. SURF. Smooth but with triangular cleavage pits like galena. H. ?

CHEM. 1. HNO_3. Bright iridescent. 2. KCN——. 3. HCl. Slowly brown, faint. Fumes tarnish bright iridescent. 4. Aq. Reg. Instantly tarnishes bright which quickly darkens to deep blue; rubs clean easily. 5. $FeCl_3$. Slowly iridescent, rubs off clean. 6. KOH ——.

DIFF. *Col. Surf.*

NOTE. Reactions may be modified by the presence of calcite, or native silver and niccolite, in the specimens tested.

PLENARGYRITE" (soft) ?

COL. Bluish white. With galena, pale bluish white.

HARD. Low. SURF. Smooth. H < plenargyrite.

CHEM. 1. HNO_3. Instantly iridescent, persistent. 2. KCN——. 3. HCl. Darkened and etched; fumes tarnish. Rubs clean easily. 4. Aq. Reg. Instantly effervesces; turns iridescent, then black. Rubs black and rough. 5. $FeCl_3$. Slowly dark brown, iridescent. Rubs clean easily. 6. KOH——.

DIFF. *Chem.* 3, 6.

NOTE. Occurs with plenargyrite exactly the same as "schapbachite" (soft), with schapbachite.

"SCHAPBACHITE" (soft) ?

COL. Bluish white. With galena, bluish white?

HARD. Low. SURF. Smooth. H. < schapbachite.

CHEM. 1. HNO_3. Instantly blackens, persistent. 2. KCN——. 3. HCl. Instantly darkened and etched. Rubs clean. 4. Aq. Reg. Instantly blackens, persistent. 5. $FeCl_3$. Rather slowly brown, then bright and iridescent. Rubs clean easily. 6. KOH. Slowly brown. Rubs clean easily.

DIFF. *Chem.* 3, 6.

COLORADOITE. See page 106.

BLUISH WHITE

YISH WHITE

CUPRITE Cu_2O

COL. White. With galena, decidedly bluish white; with proustite, the same color. Transparent deep red by oblique light.
HARD. Medium. SURF. Shiny but usually pitted. H. 3.5–4> cc.
CHEM. 1. HNO_3. Instantly plated with metallic copper, which blackens and appears to dissolve immediately, with effervescence. On washing off and drying without rubbing, a film of copper is seen on the surface, pink by oblique light. Rubs off easily, leaving a brilliant iridescent surface on some grains, and some blackened. Fumes tarnish iridescent. 2. HNO_3 conc. Effervesces, blackens and dissolves. 3. KCN. Quickly etches and develops a "cleavage" or crystal structure (?). 4. HCl. Instantly blackens and is coated with white (seen by oblique light); rubs off. Fumes tarnish brilliant iridescent. 5. HCl conc. Same as HCl. 6. Aq. Reg. Same as HCl. 7. $FeCl_3$. Rather quickly persistent dark iridescent. 8. KOH——. 9. NaOH——. 10. $(NH_4)_2S_x$. Quickly blackens and turns iridescent; shows rough solution surface on rubbing.
DIFF. *Col. Chem.* 1 and 4.

NOTE. Practically always carries intermixed native copper.

STROMEYERITE $(AgCu)_2S$

COL. White. With galena, bluish grayish white; with chalcocite, purplish.
HARD. Low (very low). SURF. Smooth or "ragged." H. 2.5–3 < cc.
CHEM. 1. HNO_3. Darkened slightly, and etched, developing a cleavage on some grains. Fumes tarnish brown, some grains more than others. Tarnish washes off. 2. KCN. Quickly brown, dries darker, and rubs off easily, leaving a clean, faintly creamy white, surface. 3. HCl——. Fumes slowly form a narrow tarnish ring around the drop. Rubs off. 4. HCl conc. Instantly dark and rough. Fumes tarnish bright iridescent. Rubs off hard, leaving a roughened surface. 5. Aq. Reg. Quickly speckled with black, rubs off to show slight roughening (?). 6. $FeCl_3$. Instantly bright iridescent, showing structure. Rubs easily to pale blues, and white, with a shallow solution pit. 7. KOH——.
DIFF. *Hard. Col. Chem.* 1.

CHALCOCITE See page 107.

POLYARGYRITE See page 114.

BROGNIARDITE See page 110.

WHITE
HARDNESS LOW
CREAMY WHITE
SAME AS SILVER, OR WHITER
$FeCl_3$

No Eff. Aq. Reg.

(HESSITE ?) **?**

COL. White. With galena, pale creamy white; with silver, same.
HARD. Low. SURF. Smooth. H. 2–3 < gn.
CHEM. 1. HNO_3. Instantly blackens with effervescence; rubs to gray, and with continued rubbing to white again, with roughened surface. 2. KCN—? 3. HCl—. 4. Aq. Reg.—. 5. $FeCl_3$. Slowly bright iridescent, persistent. 6. KOH—. 7. NaOH—. 8. $(NH_4)_2S_x$. Quickly light iridescent; rubs off easily. 9. Iodine. Fumes, instantly brilliant colors, rub off easily. Liquid, gray iridescent or yellow, persistent.
DIFF. *Surf. Chem.* 1, 4.

NOTE. Differs in properties from crystallised hessite from Felsobanya, Hungary. (See page 138.)

SILVER **Ag**

COL. White. With galena, pale creamy white.
HARD. Low. SURF. Metallic, smooth. H. 2.5–3.
CHEM. 1. HNO_3. Blackens quickly, due to the formation of a very rough solution surface, often showing crystalline etch figures. 2. KCN—. 3. HCl—. Fumes tarnish white, washes off. 4. HCl conc. same. 5. Aq. Reg. Tarnishes quickly yellow, red, blue, brilliant colors, persistent. 6. $FeCl_3$. Quickly bright iridescent, persistent. 7. KOH—. 8. $(NH_4)_2S_x$—. Fumes tarnish brownish. 9. NH_4OH—. 10. Iodine. White coating, rubs off bright iridescent.
DIFF. *Col. Surf. Chem.* 1, 5.

ALTAITE See page 128.

CREAMY WHITE

BLUISH WHITE

$FeCl_3$

KAYISH WHITE

Eff. Aq. Reg.

HUNTILITE Ag_3As ?

COL. White. With galena, pale creamy white; with silver, practically same color; with algodonite (cream), nearly pure white.
HARD. Medium. SURF. Smooth.
CHEM. 1. HNO_3. Instantly blackens, with vigorous effervescence; forms very rough surface. 2. KCN. Slowly brown, then black. Parts very resistant; rubs clean to show solution pits. 3. HCl——. Fumes tarnish deep colored, persistent. 4. Aq. Reg. Instantly iridescent; effervesces, turns bright brown; rubs to bright iridescent, persistent. 5. $FeCl_3$. Instantly iridescent, persistent. 6. KOH——.
DIFF. *Chem.* 2.

NOTE. Only specimen available is much altered, to pale yellowish gray mineral in dendritic veinlets.

Same as Silver or Whiter

Darker Than Silver
Same as Galena or Darker

WHITE
HARDNESS LOW
CREAMY WHITE
SAME AS SILVER, OR WHITER
$FeCl_3$ NEG.

KOH Neg.

$FeCl_3$ Neg

CREAMY WHITE

(MATILDITE ?) **?**

COL. White. With galena, faint creamy white, like silver; with silver, practically pure white.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3. Slowly bright yellowish brown; rubs to roughened surface. 2. KCN——. 3. HCl——. 4. HCl_3 conc.——. 5. Aq. Reg. Tarnishes and blackens quickly; rubs to rough, dark surface. 6. $FeCl_3$——. 7. KOH——.
DIFF. *Chem.* 1, 4.

NOTE. Differs from true matildite, see page 140.

GUANAJUATITE **Bi_2Se_3**

COL. White. With galena, pale creamy white; with silver, practically white. Shows intergrowth of white and pale creamy gray (orientation different ?).
HARD. Low. SURF. Smooth. H. 2.5–3.5.
CHEM. 1. HNO_3. Rapidly brilliant iridescent; rubs clean easily leaving rough surface, white portions little touched. 2. KCN——. 3. HCl——. 4. HCl conc.——. 5. Aq. Reg. White untouched; grayer part instantly iridescent, with vigorous effervescence, then orange yellow (?) coating formed, persistent, with rough surface. 6. $FeCl_3$——. 7. KOH——.
DIFF. *Chem.* 1, 4.

BLUISH WHITE

CHIVIATITE **$Pb_2Bi_4S_{11}$**

COL. Creamy white. With galena, pale creamy white; with silver, faintly grayish white.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3. Slowly tarnishes iridescent with slow effervescence. At last dark grayish. Thinly coated with white. Rubs clean easily, showing slightly roughened surface. 2. KCN——. 3. HCl——. 4. Aq. Reg. Quickly brown, with vigorous effervescence. Coated with white. Rubs clean easily, showing a pitted surface. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 1.

$FeCl_3$

BISMUTHINITE See page 130.

GALENOBISMUTITE See page 130.

GRAYISH WHITE

KOH

WITTICHENITE Cu_3BiS_3

COL. White. With galena, creamy white; with silver, practically same.

HARD. Low. SURF. Smooth. H. 3.5.

CHEM. 1. HNO_3. Turns faintly yellowish, persistent, when washed off. Fumes tarnish slowly. 2. KCN——. 3. HCl conc.——. 4. Aq. Reg. Rather quickly bright brown with slow effervescence. Fumes instantly tarnish brown. Rubs clean rather easily. 5. $FeCl_3$——. 6. KOH. Slowly faint brown, rubs clean.

DIFF. *Chem.* 1, 4.

Same as Silver or Whiter

Darker Than Silver

Same as Galena or darker

WHITE
HARDNESS LOW
CREAMY WHITE
DARKER THAN SILVER
HNO_3
$FeCl_3$ NEG.

COSALITE $Pb_2Bi_2S_5$

COL. White. With galena, creamy white; with silver, creamy white. Mixture of creamy white and pale gray needles, due possibly to difference in orientation of individuals.
HARD. Low. SURF. Smooth. H. 2.5–3.
CHEM. 1. HNO_3. Creamy part instantly blackened, with effervescence; gray hardly touched. 2. KCN——. 3. HCl. Slowly faint yellowish, rubs clean easily. 4. Aq. Reg. Instantly effervesces and tarnishes iridescent, then blackens; fumes tarnish bright brown; rubs to gray rough surface. 5. $FeCl_3$——. 6. KOH. Rather quickly bright brown, then iridescent.
DIFF. *Chem.* 1, 6.

EMPLECTITE $CuBiS_2$

COL. White. With galena, decidedly creamy (brownish); with silver, pale brownish cream.
HARD. Low. SURF. Smooth. H. 2.
CHEM. 1. HNO_3. Rather slowly light brown, with slight effervescence. Fumes tarnish slightly. Rubs clean. 2. KCN——. 3. HCl——. 4. Aq. Reg. Rapidly blackens, with effervescence. Rubs to gray, with rough solution surface. Fumes tarnish yellowish brown. 5. $FeCl_3$——. 6. KOH. Same as HNO_3, but more slowly. 7. $(NH_4)_2S_x$ ——.
DIFF. *Chem.* 1, 6.

METACINNABARITE HgS

COL. White. With galena, pale creamy and faint purple; with silver, same as with galena. Intergrowth of pale blue (cinnabar ?) and pinkish purple with creamy white.
HARD. Low. SURF. Smooth. H. 3.
CHEM. 1. HNO_3. Very slowly faintly yellowish. 2. KCN——. 3. HCl conc. Same as HNO_3. 4. Aq. Reg. Quickly blackens, with effervescence, leaving very rough surface. 5. $FeCl_3$——. 6. KOH. Same as HNO_3.
DIFF. *Chem.* 1.

SYLVANITE $AuAgTe_2$

COL. White. With galena, decided pale creamy white; with silver, pale cream.
HARD. Low. SURF. Smooth. H. 1.5–2.
CHEM. 1. HNO_3. Instantly bright brown, iridescent around edges, persistent; develops cleavage. 2. KCN——. 3. HCl——. 4. Aq. Reg. Slowly effervesces, tarnishing, and dissolving where bubbles start. Rubs clean to show pits. Fumes tarnish. With alabandite, instantly effervesces and etches, brown, persistent. 5. $FeCl_3$——. Or occasionally very slowly faint brown (doubtful). 6. KOH——.
DIFF. *Chem.* 1, 6.

FRANKEITE See page 110.

WITTICHENITE See page 121.

AIKINITE See page 101.

CHIVIATITE See page 120.

FREIESLEBENITE See page 134.

$FeCl_3$ Neg.

$FeCl_3$

Darker Than Silver

WHITE
HARDNESS LOW
CREAMY WHITE
DARKER THAN SILVER
HNO_3
$FeCl_3$

HCl Neg.

MELONITE Ni_2Te_2

COL. Cream. With galena, decidedly creamy; with silver, decidedly creamy.
HARD. Low. SURF. Smooth. H. 1–2 > gold.
CHEM. 1. HNO_3. Instantly effervesces and blackens; rubs to iridescent and gray; showing some parts not discolored. 2. KCN——. 3. HCl——. 4. Aq. Reg.——. 5. $FeCl_3$. Slowly darkens to light brown, rubs to roughened surface. 6. KOH——. 7. NaOH——. 8. $(NH_4)_2S_x$——.
DIFF. *Chem.* 1, 4

CALAVERITE $AgAuTe_2$

COL. Creamy white. With galena, decidedly deep cream color; with silver, very pale cream; with melonite, very close, nearly the same.
HARD. Low. SURF. Smooth. H. 2.5.
CHEM. 1. HNO_3. Quickly bright brown with slow effervescence; rubs to light brown with iridescent edges. Develops delicate cleavage in crystals. 2. KCN——. 3. HCl——. 4. Aq. Reg. Effervesces and slowly tarnishes green. 5. $FeCl_3$. Slowly brown, then bright iridescent; rubs clean to show solution pit. 6. KOH. Slowly tarnished brownish; rubs off to pale yellow. 7. NaOH——.
DIFF. *Chem.* 1, 4.

NOTE. Krennerite is the same as calaverite.

KALGOORLITE $HgAu_2Ag_4Te_8$?

COL. White. With galena, pale creamy brown; with silver, dull pale creamy gray; with calaverite, decidedly paler creamy (gray).
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3. Very slowly faint brown. 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly effervesces and turns iridescent, at last brilliant, with a persistent white coating. Covered with minute round pits formed by etching. 5. $FeCl_3$. Rapidly brilliant iridescent, persistent. 6. KOH——.
DIFF. *Col. Chem.* 1, 5.

SYLVANITE ? See page 122.

ARSENIC See page 136.

HESSITE See page 138.

COPPER See page 67.

TAPALPAITE See page 125.

PETZITE See page 137.

CREAMY WHITE

BLUISH WHITE

HNO_3

GRAYISH WHITE

DOMEYKITE (Mixture) Cu_3As (Sb)?

COL. White. With galena, pale yellowish creamy gray and very pale purple; with silver, same as with galena.
HARD. Low or medium. SURF. Smooth. H. 3–3.5.
CHEM. 1. HNO_3. Effervesces and blackens immediately, dissolves. 2. HNO_3 conc. Same. 3. KCN.—. Purple portion turned pinkish. 4. HCl. Develops structure in white part; purple—. 5. HCl conc. Same. 6. Aq. Reg. Instantly effervesces and etches, developing a structure. Fumes tarnish iridescent. Rubs clean easily. 7. $FeCl_3$. Instantly dark iridescent; rubs to clean rough surface. 8. KOH. Tarnishes rapidly to brilliant iridescent; rubs clean easily; purple tarnishes first. 9. $(NH_4)_2S_x$. Quickly darkens, dissolves white quicker than purple. 10. NH_4OH. Purple, bright yellowish brown, white hardly touched. 11. $K_4Fe(CN)_6$. Purple turns black, white turns brown, persistent. 12. $K_3Fe(CN)_6$. Same as 11.
DIFF. *Chem.* 1, 2.

NOTE. Only one specimen showed this mixture. Three others show the same components as algodonite.

BISMUTH Bi

COL. Creamy white, tarnishing very rapidly pale yellow, persistent. With galena, pinkish creamy white; with silver, pale pinkish creamy white, not so yellow as with galena.
HARD. Low. SURF. Metallic, smooth. H. 2–2.5 < silver.
CHEM. 1. HNO_3. Instantly blackens with vigorous effervescence; rubs to light gray coating. 2. KCN—. 3. HCl. Slowly darkens, persistent, and dissolves. 4. Aq. Reg. Rapidly blackens with effervescence; dissolved deeply. 5. $FeCl_3$. Instantly attacked, differentially, some grains hardly touched, others darkened. 6. KOH—.
DIFF. *Col. Chem.* 1, 2.

NOTE. The friction of rubbing lightly on a rouge block tarnishes bismuth yellow. This yellow is very distinctive for bismuth. If dried without rubbing, the true color is preserved.

DYSCRASITE Ag_3Sb, Ag_2Sb, etc.

COL. White. With galena, pale creamy white; with silver, pale creamy white; with argentite, white.
HARD. Low. SURF. Smooth. H. 3.5–4 ≪ niccolite.
CHEM. 1. HNO_3. Tarnishes and rapidly develops "felted" acicular structure or coarser intergrowth, differentially etched. 2. KCN. Develops brownish needles or patches rather slowly, and faint, on white ground. 3. HCl. About the same as HNO_3, not so good. 4. HCl conc. Same as HCl. 5. Aq. Reg. Sometimes with effervescence. Instantly iridescent, then pale brownish, rubs off to brilliant iridescent colors. 6. $FeCl_3$. Instantly brilliant iridescent. Differential tarnish, part turned yellowish, part with needles brilliant, persistent. 7. KOH—. 8. $(NH_4)_2S_x$. Quickly develops "felted" structure, in bright brown, then darkens to very dark green, which rubs off easily, showing structure again. 9. NH_4OH —.
DIFF. *Chem.* 1, 2.

TAPALPAITE. $3\,Ag_2(S,Te)\cdot Bi_2(S,Te)_3$? Mixture?

COL. Creamy white. (Shows intergrowth of gray and creamy white. Only creamy part of specimen is considered here. For gray part, see page 107.) With galena, creamy white; with silver, slightly creamier white.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3. Instantly blackens with effervescence; coated with white (?); fumes tarnish. Rubs to blackened, etched surface. 2. KCN—. 3. HCl. Faint brown, fumes tarnish faintly. Rubs clean. 4. Aq. Reg. Effervesces and slowly turns grayish. Fumes tarnish slightly; rubs clean easily. 5. $FeCl_3$. Instantly iridescent, darkening. Rubs to gray, rough. 6. KOH—.
DIFF. *Chem.* 1, 2, 3.

CHILENITE Ag_2Bi

COL. Creamy white. With galena, deep creamy white; with silver, slightly creamier.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3. Instantly effervesces and blackens. Dissolves; rubs clean, giving very rough surface. 2. KCN. Instantly yellowish brown; rubs clean easily. 3. HCl. Instantly iridescent, then brown, shows roughened surface. Rubs to persistent iridescent. 4. Aq. Reg. Like HCl, but more vigorous. 5. $FeCl_3$. Instantly brilliant, then darker, iridescent. Rubs to persistent iridescent gray. 6. KOH—.
DIFF. *Chem.* 2, 3.

TRALLITE. See page 106.

$FeCl_3$

Darker Than Silver

me as Galena or darker

WHITE
HARDNESS LOW
CREAMY WHITE
DARKER THAN SILVER
HNO_3 NEG.

HNO₃ Neg.

UNKNOWN (creamy, from Butte, Mont.) ?

COL. Creamy white. With galena, faintly creamy white; with silver, faintly grayish white.
HARD. Low. SURF. Smooth. H. = bn.
CHEM. 1. HNO_3——. 2. KCN. Slowly pale purple tarnish; rubs clean easily. 3. HCl——. 4. Aq. Reg.——. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 1, 2.
NOTE. Probably carries bismuth.

CREAMY WHITE

SULVANITE See page 72.

CHALMERSITE See page 72.

BERTHIERITE See page 103.

GOLD (*var.* electrum) See page 62.

BLUISH WHITE

GRAYISH WHITE

GALENA WHITE

CREAMY WHITE

BLUISH WHITE

HCl

GRAYISH WHITE

WHITE
HARDNESS LOW
GALENA WHITE
PURE WHITE
HCl

ALTAITE **PbTe**

COL. White. With galena, pure white; with silver, whiter than silver.
HARD. LOW. SURF. Smooth. H. 3+.
CHEM. 1. HNO_3. Quickly brown with effervescence, develops little crystallites ? (or crosses and treelike forms) in it. Rubs to gray, showing etch figures better. 2. KCN——. 3. HCl. Quickly bright iridescent; rubs to grayish brown, develops cracking, and leaves some uncolored patches. 4. Aq. Reg. Instantly bright iridescent tarnish; dries pale, and rubs clean readily. 5. $FeCl_3$. Instantly bright brown iridescent, persistent; rubs to gray and rough. 6. KOH——. 7. NaOH——. 8. $(NH_4)_2S_x$——. 9. Iodine, Tarnishes bright yellowish, rubs clean easily.
DIFF. *Chem.* 1.

CLAUSTHALITE **PbSe**

COL. White. With galena, pure white; with silver, white with faint bluish cast.
HARD. LOW. SURF. Smooth. H. 2.5–3.
CHEM. 1. HNO_3. Brick red coating forms instantly, which rubs off, leaving a grayish brown stain. 2. KCN——. 3. HCl. Slowly darkens, brownish, rubs clean. 4. HCl conc. Same. 5. Aq. Reg. Instantly bright iridescent; rubs to greenish gray. 6. $FeCl_3$. Slowly darkens, coated with mixed blue and yellow, yellowish by oblique light; persistent. 7. KOH——.
DIFF. *Chem.* 1.

NAUMANNITE **(Ag_2Pb) Se**

COL. White. With galena, pure white; with silver, white with bluish cast.
HARD. LOW. SURF. Smooth. H. 2.5.
CHEM. 1. HNO_3. Instantly blackens with effervescence; leaves very rough surface. 2. KCN——. 3. HCl. Slowly bright brown iridescent. 4. Aq. Reg. Instantly iridescent, and blackens with effervescence; rubs to gray. 5. $FeCl_3$. Slowly bright brown; rubs clean easily and leaves very shallow solution pit. 6. KOH——.
DIFF. *Chem.* 1.

Same as Galena or darker

GALENA WHITE

CREAMY WHITE

BLUISH WHITE

GRAYISH WHITE

HCl Neg.

HCl

WHITE
HARDNESS LOW
GALENA WHITE
PURE WHITE
HCl NEG.

GALENOBISMUTITE $PbBi_2S_4$

COL. White. Mixture (?) of silvery white and faintly yellowish white, somewhat harder. With galena, mixture of slightly different shades of creamy white; with silver, practically white.
OCC. As blades or plates.
HARD. Low. SURF. Smooth. H. 3–4.
CHEM. 1. **HNO_3**. Instantly bright brown, then black. Washes off to show whiter portion black, and grayer part coated with orange yellow. White more dissolved than other. 2. **KCN**—. 3. **HCl**—. 4. **Aq. Reg.**—. 5. **$FeCl_3$**—. 6. **KOH**—.
DIFF. *Chem.* 1, 4.

BISMUTHINITE Bi_2S_3

COL. White. With galena, whiter, and less bluish; with silver, pale grayish white. Shows different colors along and across the cleavage.
OCC. As blades and plates.
HARD. Low. SURF. Smooth. H. 2.
CHEM. 1. **HNO_3**. Blackens immediately, leaving a rough solution surface. 2. **KCN**—. 3. **HCl**—. 4. **HCl conc.** Tarnishes iridescent. 5. **Aq. Reg.** Effervesces slightly and slowly turns brown; rubs clean, showing roughened surface. 6. **$FeCl_3$**—. 7. **KOH**—. 8. **NaOH**—. 9. **$(NH)_2S_x$**—. 10. **NH_4OH**—.
DIFF. *Chem.* 1, 5.

EUCAIRITE $Cu_2Se{\cdot}Ag_2Se$

COL. White. With galena, bright white, makes galena look yellowish; with silver, bright white.
HARD. Low. SURF. Smooth. H. 2.5.
CHEM. 1. **HNO_3**. Unchanged for a moment, then rapidly tarnished and blackened. Coated with orange yellow or reddish. Rubs to greenish gray. 2. **KCN**—. 3. **HCl**—. 4. **Aq. Reg.** Instantly effervesces, then stops, and turns slowly faint brown. Rubs clean easily. Places where bubbles started marked by white coating. 5. **$FeCl_3$**. Slowly very faint brown. 6. **KOH**—.
DIFF. *Chem.* 1, 4, 5.
NOTE. Gives off selenium odor when ground on the coarse wheel.

TELLURIUM Te

COL. White. With galena, almost pure white; with silver, practically pure white; with altaite, very pale creamy white.
HARD. Low. SURF. Semi-metallic, smooth. H. 2–2.5.
CHEM. 1. **HNO_3**. Instantly effervesces and blackens; rubs to dark gray, rough surface. 2. **KCN**—. 3. **HCl**—. 4. **Aq. Reg.** Effervesces and turns brown, then black, forming white coating. Rubs to rough and gray. 5. **$FeCl_3$**. Slowly iridescent, brilliant. Persistent; shows solution surface. 6. **KOH**—.
DIFF. *Chem.* 1, 6.

UNKNOWN (white, from Bisbee, Ariz.) ?

COL. White. With galena, pure white.
HARD. Low. SURF. Smooth. H. = gn.
CHEM. 1. **HNO_3**—. 2. **KCN**. Very slowly brown, then iridescent; rubs clean easily. 3. **HCl**—. 4. **Aq. Reg.** Instantly iridescent, then black; rubs to roughened black surface. 5. **$FeCl_3$**. Quickly iridescent and blackens; rubs clean, showing roughened surface. 6. **KOH**. Rather quickly iridescent then black, persistent.
DIFF. *Chem.* 6.

LEHRBACHITE $PbSe + HgSe$

COL. Pure white. With galena, pure white.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3——. 2. KCN——. 3. HCl——. 4. Aq. Reg.——. 5. $FeCl_3$——. (Possibly $FeCl_3$ browns slightly, but observations were made in presence of soluble gangue, so reactions may be modified.) 6. KOH——.
DIFF. *Chem.* 1.

BERZELIANITE Cu_2Se

COL. Pure white. With galena, pure white.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3. Untouched an instant, then quickly bright iridescent, with a little reddish coating. Rubs to greenish gray tarnish. 2. KCN——. 3. HCl——. 4. Aq. Reg. Quickly brown, then bright iridescent. Rubs to pale gray. 5. $FeCl_3$. Rather soon light brown (seen on rinsing off reagent). Rubs clean easily. 6. KOH——.
DIFF. *Chem.* 1, 4, 5.

ANTIMONIAL BISMUTHINITE $Bi_2(S,Sb)_3$

COL. White. With galena, pure white, or with a faint creamy tinge.
OCC. Plates, usually thin, or blades, appearing as needles in the section.
HARD. Low. SURF. Smooth. H. $\ll$ en = gn.
CHEM. 1. HNO_3. Slowly tarnishes, then blackens, finally thinly coated with white. Rubs off gray, and rough. 2. KCN——. 3. HCl——. 4. HCl conc.——. 5. Aq. Reg. Quickly bright brown, then black. Rubs to persistent rough, dark surface, showing much solution. 6. $FeCl_3$——. 7. KOH——.
DIFF. *Occ. Chem.* 1, 5.

MATILDITE See page 140.

Pure White

Same as Galena or darker

WHITE
HARDNESS LOW
GALENA WHITE
SAME AS GALENA OR DARKER
HNO_3
KCN NEG.
HCl

$FeCl_3$ Neg.

GEOCRONITE $Pb_5Sb_2S_8$

COL. White. With galena, very slightly creamy, almost the same; with silver, faintly bluish white.
HARD. Low. SURF. Smooth. H. 2.5.
CHEM. 1. HNO_3. Quickly tarnishes and blackens, with white coating; rubs to iridescent gray, showing little "crystallites." 2. KCN——. 3. HCl. Very slowly faint brown. 4. HCl conc. Instantly bright brown. 5. Aq. Reg. Rapidly tarnishes brilliant iridescent. 6. $FeCl_3$——. 7. KOH——. 8. NaOH——.
DIFF. *Chem.* 1, 2, 5, 6.

MENEGHINITE $Pb_4Sb_2S_7$

COL. White. With galena, faintly grayish (or creamy white) very close.
HARD. Low. SURF. Smooth. H. = gn.
CHEM. 1. HNO_3. Untouched a moment, then very rapidly blackens. Appears gray by oblique light. Rubs to gray surface, showing smooth white *crystallites*, like geocronite. 2. KCN.—— 3. HCl. Slowly gray, some grains more than others. Fumes tarnish a bright ring. Rubs off, leaving a shallow, grayish pit. 4. Aq. Reg. Turns rather slowly iridescent. Fumes tarnish. Rubs to persistent iridescent. 5. $FeCl_3$——. 6. KOH. Very slowly colored blue or reddish.
DIFF. *Chem.* 1, 5, 7.

SEMSEYITE $Pb_7Sb_8S_{16}$

COL. White. With galena, very slightly grayish (creamy) white, almost same. Two faintly different colors observed, apparently due to orientation.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3. After a moment bright iridescent, quickly blackening; coated thinly with white. Rubs off to show persistent gray, slightly roughened surface. 2. KCN——. 3. HCl. Slowly very faint brown. Fumes tarnish narrow ring, brightly. Rubs clean easily. 4. Aq. Reg. Instantly iridescent, then blackens, with effervescence. Fumes tarnish brilliant. Rubs to faint gray, roughened surface. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 1.

HNO_3 HCl HCl

ZINKENITE See page 111.

PLAGIONITE See page 135.

JAMESONITE See page 111.

LILLIANITE $Pb_2Bi_2S_5$

COL. White. With galena, same. Shows cubic cleavage by incipient alteration.
HARD. Low. SURF. Smooth. H. = gn?
CHEM. 1. HNO_3. Instantly iridescent. Rubs clean and smooth easily. 2. KCN——. 3. HCl. Slowly light brown (differential action on different grains). Fumes tarnish bright. Rubs off rather easily, smooth and clean. 4. Aq. Reg. Instantly dark brown, then nearly black, coated with white. Fumes tarnish a narrow rim, bright. Rubs clean and smooth easily. 5. $FeCl_3$. Slowly bright iridescent. Rubs smooth and clean easily. 6. KOH——.
DIFF. *Surf. Chem.* 1.

KCN Neg.

GALENA PbS

COL. White. With silver, bluish white.
HARD. Low. SURF. Smooth, but usually shows triangular pits. H. 2.5–2.75.
CHEM. 1. HNO_3. Blackens quickly with a dark, persistent coating. 2. KCN——. 3. HCl. Slowly faint brown. 4. HCl conc. Quickly brown, fumes tarnish. 5. Aq. Reg. Instantly blackens. 6. $FeCl_3$. Bright, iridescent, persistent. 7. KOH——. 8. $(NH_4)_2S_x$——. 9. NH_4OH ——.
DIFF. *Surf. Chem.* 1.

NOTE. A specimen of galena from Central City, Col., intergrown with tellurides and native tellurium, with HNO_3 is unchanged for an instant, then turned dark brown; rubs clean to show smooth solution pit, cream colored.

Galena with intergrown pure white or creamy minerals, such as selenides or tellurides is apt to appear very purple, and care must be taken not to confuse it with *purple "galena,"* which is really purplish, as is shown by comparing it with ordinary galena.

STEINMANNITE PbS (As, Sb) (var. galena)

COL. White. With galena, same.
HARD. Low. SURF. Smooth, with triangular cleavage pits. H = gn?
CHEM. 1. HNO_3. Instantly iridescent, then blackens with effervescence; coated with white. Rubs to gray rough surface. 2. KCN——. 3. HCl. Rather quickly blackens, and is coated with white. Rubs off to show rough gray surface, with spots which rub clean and smooth. 4. Aq. Reg. Instantly iridescent, then black. Coated thinly with white; rubs clean easily and shows slightly roughened surface. 5. $FeCl_3$. Slowly bright iridescent. Rubs clean and smooth easily. 6. KOH——.
DIFF. *Surf. Chem.* 1.

TETRADYMITE? $Bi_2(TeS)_3$

COL. White. With galena, very slightly yellowish or grayish, practically the same; with silver, pale, decidedly purplish grayish white; with bismuthinite, decidedly purplish gray.
HARD. Low. SURF. Smooth. H. 1.5–2.
CHEM. 1. HNO_3. Rather rapidly deep brown, then black fumes tarnish brownish. Rubs to rough, light gray surface. 2. KCN——. 3. HCl. Slowly bright brown; rubs to uneven pale brown. 4. HCl conc. Quickly brown, then iridescent. 5. Aq. Reg. Slowly brown, somewhat persistent. 6. $FeCl_3$. Slowly faint brown, persistent. Rubs clean, shows solution surface. 7. KOH——. 8. $(NH_4)_2S_x$. Darkens to deep grayish brown, rubs clean.
DIFF. *Surf. Chem.* 1, 2.

KCN

NOTE. Shows galena (?) cleavage, and may possibly be only galena carrying tellurium. Intergrown with a little of a creamy mineral which might be the true tetradymite.

Same as Galena or darker

GALENA WHITE

CREAMY WHITE

BLUISH WHITE

GRAYISH WHITE

HCl Neg.

HCl

WHITE
HARDNESS LOW
GALENA WHITE
SAME AS GALENA OR DARKER
HNO_3
KCN NEG.
HCl NEG.
FeCl NEG.

No Eff. HNO_3

NAGYAGITE $Au_2Pb_{16}Sb_2Te_6S_{15}$ (Hintze)
COL. White. With galena, very pale grayish white; nearly same; with silver, pale bluish grayish white.
HARD. Low. SURF. Smooth. H. 1–1.5.
CHEM. 1. HNO_3. After a short time suddenly iridescent, bright; rubs to dark gray. 2. KCN——. 3. HCl——. 4. Aq. Reg. Quickly iridescent, then black. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 1.

FREIESLEBENITE $(PbAg_2)_3Sb_4S_{11}$
COL. White. With galena, pale creamy white; with silver, pale (brownish) cream.
HARD. Low. SURF. Smooth. H. 2+.
CHEM. 1. HNO_3. Blackened and roughened. 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly effervesces then turns bright brown iridescent, rubs clean easily. 5. $FeCl_3$——. 6. KOH——. 7. NaOH——. 8. $(NH_4)_2S_x$——
DIFF. *Chem.* 1, 6.

GUITERMANITE $Pb_2As_2S_5$
COL. White. With galena, very close, slightly grayish (?).
HARD. Low. SURF. Smooth.
CHEM. 1. HNO. Instantly bright iridescent. Rubs clean, leaving roughened surface. 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly iridescent, with effervescence; then darkens. Rubs to gray roughened surface. 5. FeCl——. 6. KOH——.
DIFF. *Chem.* 1, 4.

BEEGERITE $Pb_6Bi_2S_9$
COL. White. With galena, very pale creamy white; with silver, decidedly grayish white.
HARD. Low. SURF. Smooth. H. < cp.
CHEM. 1. HNO_3. Parts instantly, parts slowly, iridescent. Fumes tarnish brown. Rubs easily to pale gray. 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly effervesces slowly, and turns bright iridescent, then black. Fumes tarnish bright. Parts coated with white. Rubs to iridescent gray. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 1, 4.

JORDANITE ? $Pb_4As_2S_7$?
COL. White. With galena, very pale grayish white, very close; with tetrahedrite, practically white.
HARD. Low. SURF. Smooth. H. < sl.
CHEM. 1. HNO_3. Untouched a moment, then slowly light gray. Rubs very pale gray, slightly rough. 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly iridescent, effervesces and blackens. Rubs to gray roughened surface. 5. FeCl——. 6. KOH——.
DIFF. *Chem.* 1.

ANDORITE $Pb_3Ag_2Sb_2S_8$
COL. White. With galena, very pale (creamy) grayish white; with silver, dull grayish white; with tetrahedrite, much lighter, grayish white.
HARD. Low. SURF. Smooth. H. = 3–3.5?
CHEM. 1. HNO_3. Rather slowly iridescent, rubs clean easily. 2. KCN——. 3. HCl——. 4. Aq. Reg. Slowly brown, then brilliant iridescent, with increasing effervescence. Fumes tarnish brilliant ring quickly. White coating formed. Rubs off to show deeply etched surface. 5. $FeCl_3$——. 6. KOH. Slowly pale brown, darkening to bluish iridescent. Rubs clean easily.
DIFF. *Chem.* 4, 6.

EPIBOULANGERITE $Pb_3Sb_2S_6$
COL. Galena white. With galena, practically the same. Faintly greenish gray.
HARD. Low. SURF. Smooth. H.
CHEM. 1. HNO_3. Untouched a moment, then blackens, and is coated with white. Rubs off to show gray surface studded with little white crystals which have rubbed clean. 2. KCN——. 3. HCl——. Fumes tarnish slightly. 4. Aq. Reg. Instantly effervesces and blackens. Fumes tarnish bright iridescent. Rubs to gray, etched surface. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 1.

UNKNOWN (near andorite) ?
COL. White. With galena, very pale (greenish) grayish white, rather close.
HARD. Low. SURF. Smooth. H. gn.
CHEM. 1. HNO_3. Very slowly brown and iridescent; rubs to faint gray. 2. KCN——. 3. HCl——. 4. HCl conc.——. Fumes tarnish light brown. 5. Aq. Reg. Instantly effervesces and turns iridescent, darkens, with little or no white coating. Fumes tarnish brilliant iridescent; rubs to gray roughened surface, fumes rub clean. 6. KOH——. 7. $FeCl_3$——.
DIFF. *Chem.* 6.

NOTE. Very close to andorite in properties.

BISMUTHINITE See page 130.
LENGENBACHITE See page 141.
BAUMHAUERITE See page 108.
JAMESONITE See page 111.

BOULANGERITE $Pb_3Sb_2S_6$

COL. White. With galena, very pale grayish white, with silver, very pale bluish grayish white.
HARD. Low. SURF. Smooth. H. 2.5–3.
CHEM. 1. HNO_3. Rapidly blackens with effervescence. 2. KCN——. 3. HCl——. 4. Aq. Reg. Same as HNO_3 but slower. 5. $FeCl_3$——. 6. KOH——. 7. NaOH——. 8. $(NH_4)_2S_x$——.
DIFF. *Chem.* 1.

$FeCl_3$ Neg

KCN Neg.

DOGNACSKAITE Bi,Cu,S ?

COL. White. With galena, pale creamy white; with silver, pale grayish white. Also shows some intergrowth of a bluish mineral, same hardness.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3. Instantly effervesces and tarnishes iridescent, then blackens. Coated with pale yellowish white. Fumes tarnish, rubs to rough black. 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly effervesces and tarnishes brown. Fumes tarnish. Rubs clean easily, showing slight solution pits where bubbles started. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 1, 6.

HORSFORDITE Cu_6Sb ?

COL. White. With galena, very pale creamy, almost same; with silver, pale bluish or grayish white.
HARD. Low. SURF. Smooth. H. 4–5.
CHEM. 1. HNO_3. Instantly blackens with slight effervescence; rubs to light gray iridescent. 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly etches; part brown, part little changed; rubs to pale gray. Fumes tarnish bright. 5. $FeCl_3$——. 6. KOH. Slowly faint brownish and bluish; rubs faint.
DIFF. *Chem.* 1, 6.

PLAGIONITE $Pb_5Sb_8S_{17}$

COL. White. With galena, very pale grayish white, very near.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3. Untouched a moment, then quickly dark iridescent, with effervescence; finally black. Rubs to persistent gray. 2. KCN——. (Or very slowly faint brown ?). 3. HCl——. Fumes tarnish bright. 4. Aq. Reg. Instantly effervesces and tarnishes bright. Fumes tarnish brilliant. Rubs clean easily. 5. $FeCl_3$——. 6. KOH. Slowly brown, then purple, then blue, iridescent. Washes to pale blue. Rubs clean very easily.
DIFF. *Chem.* 1, 6

$FeCl_3$

KCN

ϕ^e as Galena or darker

CHIVIATITE See page 120.

WHITE
HARDNESS LOW
GALENA WHITE
SAME AS GALENA OR DARKER
HNO_3
KCN

KERMESITE Sb_2S_2O

COL. White. With galena, slightly darker, almost same; with silver, pale bluish white, very nearly same. *Red transparent* by oblique light.

HARD. Low. SURF. Smooth. H. 1–1.5.

CHEM. 1. HNO_3. Quickly light brown, persistent. 2. KCN. Slowly darkens, slightly, and rubs to lighter brown. 3. HCl——. 4. Aq. Reg. Effervesces vigorously, and darkens slightly. 5. $FeCl_3$——. 6. KOH. Instantly iridescent, then coated with bright yellow, which rubs off easily.

DIFF. *Col. Chem.* 4, 6.

STIBNITE Sb_2S_3

COL. White. With galena, very faintly creamy, with silver, faint grayish white. Differently oriented sections vary slightly in color.

HARD. Low. SURF. Smooth. H. 2.

CHEM. 1. HNO_3. Quickly darkens, at last dark brown. 2. KCN. Dissolves and roughens surface, but does not change color. 3. HCl——. 4. Aq. Reg. Blackens rapidly with effervescence. 5. $FeCl_3$——. 6. KOH. Quickly coated with bright orange yellow, soon turning reddish brown. Washes off easily, leaving rough surface. 7. NaOH——. 8. NH_4OH——.

DIFF. *Col. Chem.* 4, 6.

HESSITE Ag_2Te

COL. White. With galena, very slightly creamy, almost the same; with silver, distinctly bluish gray.

HARD. Low. SURF. Smooth. H. = 2–3 < gold.

CHEM. 1. HNO_3. Instantly iridescent, then darkens to dark brown. Rubs clean, leaving a roughened surface. 2. KCN. Slowly blackens and dissolves, giving a very rough surface. 3. HCl——? 4. Aq. Reg. Instantly brilliant iridescent with effervescence. Fumes tarnish brilliant. Rubs clean easily. 5. $FeCl_3$. Instantly iridescent. Rubs clean easily. 6. KOH——.

DIFF. *Chem.* 5 (?), 6.

GUEJARITE See page 103.

BROGNIARDITE See page 110.

HCl Au

KCN

ge as Galena or darker

GALENA WHITE

CREAMY WHITE

BLUISH WHITE

GRAYISH WHITE

HNO₃ Neg.

HCl

White
Hardness Low
Galena White
Same as Galena or Darker
HNO_3 Neg.
KOH Neg.

No Eff. Aq. Reg.

JALPAITE $3\,Ag_2S{\cdot}Cu_2S$?

Col. White. With galena, very pale creamy gray, almost same; with silver, dull grayish white; with argentite, pale brownish cream; with tetrahedrite, very close, almost same (?).
Hard. Low. Surf. Smooth. H. 2–2.5.
Chem. 1. HNO_3—. 2. HNO_3 conc.—. 3. **KCN.** Very slowly browned, develops scratches; rubs off rather easily. 4. HCl. Slowly effervesces a little, solution turns green, surface is roughened. 5. **Aq. Reg.** Instantly iridescent, deepens rapidly, persistent. 6. $FeCl_3$—. 7. KOH—.
Diff. *Chem.* 3, 5.

MALTILDITE $AgBiS_2$

Col. White. With galena, very slightly creamy or grayish white, almost same; with silver, distinctly grayish white; with matildite (?) from Japan, grayer, less creamy.
Hard. Low. Surf. Smooth. H. 2.5?
Chem. 1. HNO_3—. 2. KCN—. 3. HCl—. 4. HCl conc.—. 5. **Aq. Reg.** Fumes instantly tarnish brilliant iridescent, acid same, less quickly, and darker finally. Effervesces slightly (?). Rubs easily to a clean, very slightly roughened surface. 6. $FeCl_3$—. 7. KOH—.
Diff. *Chem.* 2, 5.

UNKNOWN (Tonopah) See page 114.

Eff. Aq. Reg.

KOH Neg.

SCHIRMERITE $(Ag_2Pb)_3Bi_4S_9$

COL. White. With galena, practically the same (faintly creamier).
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3——. 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly iridescent, then blackens, with effervescence; coated with white. Rubs to roughened iridescent surface. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Col. Chem.* 4, 6.

RATHITE $Pb(As,Sb)_2S$?

COL. White. With galena, very pale bluish (grayish) white.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3——. 2. KCN——. 3. HCl——. 4. Aq. Reg. Effervesces quickly and turns brown, then black; thinly coated with white. Rubs to rough gray surface. 5. $FeCl_3$——. 6. KOH. Rather quickly pale brown, then pale purple and blue iridescent. Rubs to very pale purplish color.
DIFF. *Chem.* 6.

NOTE. Same chemical properties as seligmannite, but looks bluish instead of creamy.

LENGENBACHITE $Pb_6(AgCu)_2As_4S_{13}$

COL. White. With galena, very pale grayish white; with tetrahedrite, distinctly whiter.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3——? (Edge of specimen slowly tarnished iridescent, but perhaps due to sealing wax mount.) 2. KCN——. 3. HCl——. 4. Aq. Reg. Instantly iridescent, effervesces, finally blackens. Rubs to faintly gray, roughened surface. 5. $FeCl_3$——. 6. KOH——.
DIFF. *Chem.* 4, 6.

CINNABAR HgS

COL. White. With galena, pale bluish gray; with tetrahedrite, dull grayish white. *Transparent brilliant red* with oblique light.
HARD. Low. SURF. Smooth. H. 2–2.5.
CHEM. 1. HNO_3——. 2. KCN——. 3. HCl conc,——. 4. Aq. Reg. Effervesces and darkens, iridescent. Rubs clean. 5. $FeCl_3$——. 6. KOH——. 7. $(NH_4)_2S_x$——.
DIFF. *Col.*

KOH

Same as Galena or darker

MATILDITE See page 140.

POLYBASITE See page 105.

BOURNONITE See page 92.

GALENA WHITE

CREAMY WHITE

BLUISH WHITE

GRAYISH WHITE

HNO₃ Neg.

HCl

WHITE
HARDNESS LOW
GALENA WHITE
SAME AS GALENA OR DARKER
HNO_3 NEG.
KOH

LIVINGSTONITE $HgSb_4S_7$

COL. White. With galena, very pale grayish white, practically the same; with silver, very pale (bluish) grayish white. *Transparent deep red* by oblique light.
HARD. Low. SURF. Smooth. H. 2.
CHEM. 1. HNO_3——. 2. HNO_3 conc.——. 3. KCN. Very slowly faint gray. 4. HCl——. 5. HCl conc.——. 6. Aq. Reg. Slowly brown with effervescence. 7. $FeCl_3$——. 8. KOH. Instantly bright yellowish brown.
DIFF. *Col. Chem.* 5, 6, 8.

STEPHANITE Ag_5SbS_4

COL. White. With galena, very pale grayish white; with silver, decidedly bluish gray; with argentite, almost pure white; with tetrahedrite, bluish gray; with proustite, nearly pure white.
HARD. Low. SURF. Smooth. H. 2–2.5.
CHEM. 1. HNO_3——. 2. KCN. Immediately darkens; rubs clean easily, leaving brown edged cracks. 3. HCl——. Fumes very slowly brown, then iridescent. Rubs off. 4. HCl conc.——. Fumes tarnish iridescent, persistent, forming a brilliant ring on the surface. 5. Aq. Reg. Instantly iridescent, blackens with slight effervescence; rubs to dark gray, persistent, and shows a shallow solution pit. Fumes tarnish brighter than acid. 6. $FeCl_3$. Slowly develops little black flecks, white by oblique light. Rubs clean easily. 7. KOH. Rapidly darkens to dark brown; rubs clean easily, showing solution surface. 8. NaOH. Same as KOH, but not as rapid. 9. NH_4OH——. 10. $(NH_4)_2S_x$. Slowly brown, rubs clean easily.
DIFF. *Chem.* 4, 7.

SARTORITE $PbAs_2S_4$

COL. White. With galena, very close.
HARD. Low. SURF. Smooth. H. = 3?
CHEM. 1. HNO_3——. 2. KCN——. 3. HCl——. 4. Aq. Reg.——, or very slowly faint brownish (doubtful, because of mounting wax). 5. $FeCl_3$——. 6. KOH. Quickly faint gray (?), slowly etches, developing structure. Rinses off white showing etching lines (cleavage or structure).
DIFF. *Chem.* 4, 6.

DUFRENOYSITE $Pb_2As_2S_5$

COL. White. With galena, very close (slightly creamy ?).
HARD. Low. SURF. Smooth. H. = 3?
CHEM. 1. HNO_3——. 2. KCN——. Or very pale tarnish, slowly? 4. Aq. Reg. Quickly brown, then iridescent, effervesces slowly. Finally very dark, with white coating. Rubs to blackened rough surface. 5. $FeCl_3$——. 6. KOH. Rather quickly pale iridescent, developing different grains; then gray. Rubs clean easily, showing very strongly differential etching.
DIFF. *Chem.* 4, 6.

NOTE. Called binnite by Heusser.

BERTHIERITE See page 103.

MIARGYRITE See page 115.

RAY

KOH

...e as Galena or darker

GRAY
HARDNESS HIGH
HCl CONC.

FRANKLINITE $FeZnMnO\cdot(FeMn)_2O_3$

COL. Gray. With galena, dull gray; with sphalerite, distinctly lighter; with hematite, grayer.
HARD. High. SURF. Shiny, pitted. H. 5.5–6.5.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl conc,—. Acid turns yellowish brown, slowly. 4. Aq. Reg. Same as HCl conc. 5. KOH—. 6. $FeCl_3$—.
DIFF. *Col. Chem.* 3.

NOTE. Very hard to polish free from pits.

PSILOMELANE H_4MnO_5 ?

COL. Gray. With sphalerite, somewhat lighter, and creamy; with galena, dull gray.
HARD. High. SURF. Smooth. H. 5–6.
CHEM. 1. HNO_3 conc.—. 2. HCl. Quickly darkens, rubs to pale brown. 3. HCl conc. Immediately blackens and dissolves. Acid turns brown. 4. Aq. Reg. Very slowly faint brown, persistent. 5. KOH—. 6. $FeCl_3$—.
DIFF. *Col. Chem.* 2, 3.

MAGNETITE See page 91.

HCl Conc.

HARDWICK ---

GRAY
HARDNESS HIGH
HCl CONC. NEG.

Aq. Reg. Neg.

HCl Conc. Neg.

CASSITERITE SnO_2

COL. Gray. With galena, dull brownish (?) gray; with sphalerite, slightly lighter (?) and creamy; with hematite, dull gray; with magnetite, dull gray; sometimes transparent yellow or brown by oblique light.
HARD. High. SURF. Shiny, pitted. H. 6–7.
CHEM. 1. HNO_3—. 2. HNO_3 conc.—. 3. KCN—. 4. HCl conc.—. 5. Aq. Reg.—. 6. $FeCl_3$—. 7. KOH—.
DIFF. *Col. Chem. inertness.*
NOTE. Very hard to polish free from pits.

LIMONITE $2\,Fe_2O_3{\cdot}3\,H_2O$?

COL. Gray. With galena, pale slate gray to dull gray; with sphalerite, slightly bluish gray. Often transparent reddish brown or yellow by oblique light. Color appears brighter on a smooth surface than on a rough one.
HARD. High. SURF. Smooth, or pitted. H. 5–5.5.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl conc,—. 4. Aq. Reg.—. 5. $FeCl_3$—. 6. KOH—.
DIFF. *Col. Chem.*

CHROMITE $FeCr_2O_4$

COL. Gray. With galena, very dull gray; with sphalerite, darker, dull gray.
HARD. High. SURF. Shiny, much pitted. H. 5.5.
CHEM. 1. HNO_3—. 2. KCN—. 3. HCl conc.—. 4. Aq. Reg.—.
DIFF. *Col. Surf.*
NOTE. Very hard to polish free from pits.

HCl Conc.

RUTILE See page 90.

FRANKLINITE See page 144.

HEMATITE See page 90.

ILMENITE See page 90.

URANINITE (A uranate of uranyl with other bases)

COL. Gray. With sphalerite, slightly darker and faintly brownish (?).
HARD. High. SURF. Smooth. H. 5.5 > sl.
CHEM. 1. HNO_3——. 2. KCN——. 3. HCl——. 4. HCl conc,——. 5. Aq. Reg. Slowly blackens, rubs off to darker gray, roughened surface. 6. $FeCl_3$. Slowly darkens, roughens slightly, persistent. 7. KOH——.
DIFF. *Col. Chem.* 5, 6.

HCl Neg.

SPHALERITE **ZnS**

COL. Gray. With galena, bright steely gray. Sometimes bluish, or slate gray, or reddish when in very small areas. Transparent yellow to brown by oblique light. Color only slightly different for black and for pure varieties.
HARD. Medium. SURF. Smooth. H. 3.5–4 =or > cp.
CHEM. 1. **HNO_3**. Faintly browned, slowly, often showing crystal structure. 2. **HNO_3 conc.** Same. 3. **KCN**——. 4. **HCl**——. 5. **HCl conc.**——. 6. **Aq. Reg.** Instantly effervesces and blackens. Rubs off to show rough etched surface. Fumes tarnish brown. 7. **$FeCl_3$**——. 8. **KOH**——. 9. **$(NH_4)_2S_x$**——. 10. **$K_4Fe(CN)_6$**——. 11. **$K_3Fe(CN)_6$**——. 12. **Iodine**——. 13. **NH_4OH**——.
DIFF. *Col. Chem.* 1.

WURTZITE **ZnS**

COL. Gray. Transparent yellow or brown by oblique light. Same color as sphalerite.
HARD. Medium. SURF. Smooth. H. 3.5–4.
CHEM. 1. **HNO_3**. Slowly faint brown. 2. **HNO_3 conc.** Same. 3. **KCN**——. 4. **HCl**——. 5. **HCl conc.**——. 6. **Aq. Reg.**——. 7. **$FeCl_3$**——. 8. **KOH**——.
DIFF. *Chem.* 1.

VOLTZITE **Zn_5S_4O**

COL. Gray. With sphalerite, slightly lighter gray. Transparent reddish yellow or brown by oblique light.
HARD. Medium. SURF. Smooth. H. 4–4.5.
CHEM. 1. **HNO_3**——. Fumes tarnish faintly. 2. **KCN**——. 3. **HCl**——. 4. **Aq. Reg.**——. Fumes tarnish brown. 5. **$FeCl_3$**——. 6. **KOH**——.
DIFF. *Chem.* 1.

ERYTHROZINCITE **(MnZn)S**

COL. Gray. About like limonite.
OCC. Coatings and veinlets on and in pyrite.
HARD. Low to medium. SURF. Smooth. H. $\ll$ py.
CHEM. 1. **HNO_3**——? 2. **KCN**——. 3. **HCl**——. 4. **Aq. Reg.**——. 5. **$FeCl_3$**——. 6. **KOH**——.
DIFF. *Chem.* 1, 4.

URANINITE See page 147.

ARGYRODITE See page 105.

CUPRODESCLOIZITE $(PbZnCu)_4V_2O_9 \cdot H_2O$

Col. Gray. With galena, dull gray. Sometimes transparent greenish or brownish with oblique light.
Hard. Medium. Surf. Smooth. H. 3.5.
Chem. 1. HNO_3. Quickly blackens and dissolves; shows yellow coating with oblique light. 2. KCN——. 3. HCl same as HNO_3. 4. Aq. Reg. Dissolved, coated quickly with yellowish green, which shows white after acid is washed off. Fumes tarnish iridescent instantly, then tarnish turns black. 5. $FeCl_3$——. 6. KOH——.
Diff. *Chem.* 1.

CUPRITE See page 117.

ALABANDITE See page 96.

TENORITE See page 92.

DELAFOSSITE See page 92.

GRAY
HARDNESS LOW

LORANDITE $TlAsS_2$

COL. Gray. With galena, distinctly gray; with sphalerite, slightly darker. Transparent orange red by oblique light.
HARD. Low. SURF. Smooth.
CHEM. 1. HNO_3——. 2. KCN——. 3. HCl——. 4. Aq. Reg.——. 5. $FeCl_3$——. 6. KOH. Instantly coated with orange. Rubs off to show very rough solution surface.
DIFF. *Chem.* 6.

STANNITE See page 108.

"PETZITE" See page 106.

ARGYRODITE See page 105.

ERYTHROZINCITE See page 148.

TAPALPAITE" (GRAY) See page 107.

MISCELLANEOUS TABLES

INDEX

CONDENSED DETERMINATIVE TABLE

The more important minerals are printed in conspicuous type, so that they can be readily picked out. The parentheses around a mineral name indicate that the reaction changes in character as it progresses, and that the first stage places the mineral in a certain group, while the final effect puts it elsewhere. For example, *marcasite* first turns brown, and then finally blackens, with HNO_3, and so is referred to in parentheses under **HNO_3 — Eff. — Browns**, and without parentheses under **HNO_3 — Eff. — Blackens — $FeCl_3$ neg.**

HNO_3 Neg.

KCN neg.

Aq. Reg. neg.

Cassiterite	Lorandite
Chromite	**Magnetite**
Erythrozincite	Millerite
Franklinite	**Molybdenite**
Hematite	Rutile
Ilmenite	Sartorite
Lehrbachite	
Limonite	

Aq. Reg.

No Eff.	**Eff.**
Berthierite	**Bournonite**
Chalcostibite	Dufrenoysite
Chalcopyrite	Kalgoorlite
Delafossite	Lengenbachite
Matildite (?)	(Onofrite)
Psilomelane	Rathite
Regnolite	Schirmerite
Sperrylite	Seligmannite
Tenorite	Stützite
Tiemannite	Vrbaite
Uraninite	

KCN

KOH neg.

Argentite
Argyrodite
Covellite
Gold
Jalpaite
Onofrite
Polybasite

KOH

Livingstonite
Miargyrite
Orpiment
Proustite
Pyrargyrite
Stephanite

Fumes HNO_3

Chalmersite	Sulvanite
Enargite	**Tennantite**
Hauerite	**Tetrahedrite**
Luzonite	Voltzite
Pearceite	
Polyargyrite	

HNO_3

Blackens $FeCl_3$ neg.

No Eff.	
Bismuthinite	Glaucodot
Cuprodescloizite	Guejarite
Epiboulangerite	**Jamesonite**
Freieslebenite	Jordanite
Galenobismutite	Meneghinite
Geocronite	**Realgar**
Gersdorffite	Semseyite

Blackens $FeCl_3$ neg.

Eff.	
Aikinite	**Marcasite**
Alabandite	Dognacskaite
Algodonite (gray)	Horsfordite
Arsenopyrite	Mohawkite (cream)
Boulangerite	**Niccolite**
Cinnabar	Zinkenite
Cosalite	

No Eff. (*continued*)	Eff. (*continued*)
$FeCl_3$	**$FeCl_3$**
Breithauptite Clausthalite Eucairite **Galena** **Silver** Tetradymite	Algodonite (cream) **Arsenic** **Bismuth** Chilenite **Cuprite** Hessite (?) Huntilite Maucherite Melonite Mohawkite (gray) Naumannite Petzite (?) Rickardite Safflorite Skutterudite **Smaltite** Steinmannite Tapalpaite Tellurium
Browns **Slowly**	**Browns**
Aguilarite Baumhauerite Brogniardite **Cobaltite** Coloradoite Crookesite Cylindrite **Famatinite** Hauchecornite Kermesite Linnaeite Löllingite Matildite (?) Metacinnabarite Pentlandite **Polydymite** (Polytelite) **Pyrrhotite** **Sphalerite** Stylotypite Wittichenite Wurtzite	Altaite (Arsenic) **Bornite** **Calaverite** **Petzite** **Pyrite** Whitneyite Willyamite **(Marcasite)**
Quickly	
Chloanthite Emplectite Frankeite (Galenobismutite) **Hessite** **(Jamesonite)** Rammelsbergite **(Stannite)** **Stibnite** **Sylvanite** (Teallite) (Tetradymite) (Ullmannite) " Bronze Enargite "	
Turns iridescent **$FeCl_3$ neg.**	**Turns iridescent**
Andorite Beegerite (Cylindrite) (Frankeite) **Freibergite** (Gersdorffite) Guanajuatite (Gucjarite) Guitermanite Lengenbachite Nagyagite Polytelite Semseyite **Stannite** Sternbergite Ullmannite	**(Arsenopyrite)** Chiviatite (Dognacskaite) Kallilite (Steinmannite) (Willyamite)
$FeCl_3$	
Berzelianite (Breithauptite) (Coloradoite) Dyscrasite **(Hessite)** Lillianite Rezbanyite Teallite	
Turns blue	**Turns blue**
Umangite	**Chalcocite**
Color unchanged	**Color unchanged**
Copper Stromeyerite	**Realgar**

ODOR AND STREAK OF MINERALS

A number of minerals carrying arsenic give off a characteristic odor when ground dry on the coarse carborundum wheel. Many arsenic minerals do not give this, however, so absence of odor does not necessarily mean absence of arsenic. Selenium occasionally gives an odor under the same conditions. Some minerals leave a characteristic streak when polished on the canvas wheel. These several groups of minerals are listed below.

ARSENIC ODOR

Arsenic
Arsenopyrite
Chloanthite
Glaucodot
Löllingite
Safflorite
Smaltite
Skutterudite
(Enargite under some conditions, but not usually)

SELENIUM ODOR

Eucairite
(Probably some other selenides also, but none were obtained large enough to test fairly in this respect.)

STREAK

Tetrahedrite — reddish
Tennantite — reddish
Hauerite — orange
Sphalerite — brown to whitish
Limonite — brown to reddish

MINERALS TABULATED BY ELEMENTS

(Brackets indicate that the enclosed mineral has not been studied in this investigation)

ARSENIC

Algodonite Cu_6As (mixture)
Argyropyrite Ag, Fe, S, As
Arsenic As
Arsenopyrite FeAsS
[Badenite $(CoFeNi)_3(AsBi)_2$]
Baumhauerite $Pb_4As_6S_{13}$
"Bronze Enargite" (CuSn), (AsSb), S ?
Chloanthite $NiAs_2$
Cobaltite CoAsS
Domeykite Cu_2As (+Sb) (mixture)
Dufrenoysite $Pb_2As_2S_5$
Enargite Cu_3AsS_4
[Epigenite $R_7As_2S_{12}$ (R = 8 Cu + 3 Fe)]
Gersdorffite NiAsS
Glaucodot (CoFe)AsS
Guitermanite $Pb_3As_4S_9$
Huntilite Ag_3As ?
[Hutchinsonite Tl, Ag, Cu, Pb, As, S ?]
Jordanite $Pb_4As_2S_7$
Kallilite NiBiS + As, Sb ?
Lengenbachite $Pb_6(AgCu)_2As_4S_{13}$
[Liveingite $Pb_4As_6S_{17}$]
Löllingite $FeAs_2$
Lorandite $TlAsS_2$
Luzonite Cu_3AsS_4
Maucherite Ni_2As_2
Mohawkite Cu_2As (mixture)
Niccolite NiAs
Orpiment As_2S_3
Pearceite Ag_9AsS_6
Proustite Ag_3AsS_3
Rammelsbergite $NiAs_2$
Rathite Pb, As, Sb, S ?
Realgar AsS
Regnolite $Cu_7As_2S_{12}$
Safflorite $CoAs_2$
Sartorite $PbAs_2S_4$
Seligmannite $CuPbAsS_3$
Skutterudite $CoAs_3$
Smaltite $CoAs_2$
[Smithite $AgAsS_2$]
Sperrylite $PtAs_2$
Steinmannite Pb(As, Sb, S)
Tennantite $Cu_3As_2S_7$
[Trechmannite $AgAsS_2$]
Vrbaite $TlAs_2SbS_5$
Whitneyite Cu_9As
[Xanthoconite Ag_3AsS_4]

ANTIMONY

Andorite $PbAg_2Sb_6S_9$
Berthierite $FeSb_2S_4$
Boulangerite $Pb_5Sb_4S_{11}$
Bournonite $(PbCu_2)_2Sb_2S_6$
Breithauptite NiSb
Brogniardite $PbAg_2Sb_2S_5$?
"Bronze Enargite" (CuSn), (AsSb), S ?
Chalcostibite $CuSbS_2$
Cylindrite $3\,PbSnS_2 + SnFeSb_2S_6$
[Diaphorite $(PbAg_2)_3Sb_2S_{11}$]
Domeykite Cu_3As + (Sb) (mixture)
Dyscrasite Ag_3Sb
[Eichbergite (CuFe)$Bi_3Sb_3S_6$]
Epiboulangerite $Pb_3Sb_2S_6$
Famatinite Cu_3SbS_4
Frankeite $3\,PbSnS_2 + Pb_2FeSb_2S_6$
Freibergite $(CuAg)_6Sb_2S_7$
Freieslebenite $(PbAg_2)_5Sb_4S_{11}$
Geocronite $Pb_5Sb_2S_8$
Guejarite $Cu_2Sb_4S_7$
Hauchecornite $(NiCo)_7(BiSbS)_8$
[Histrixite $Cu_5Fe_5Bi_{14}Sb_4S_{37}$ (mixture) ?]
Horsfordite Cu_5Sb ?
Jamesonite $Pb_2Sb_2S_5$
Kallilite NiBiS + As, Sb ?
Kermesite Sb_2S_2O
Kobellite $Pb_2(BiSb)_2S_5$ (mixture ?)
Livingstonite $HgSb_4S_7$
Meneghinite $Pb_4Sb_2S_7$
Miargyrite $AgSbS_2$
Nagyagite $Au_2Pb_{10}Sb_2Te_6S_{15}$
Plagionite $Pb_5Sb_8S_{17}$
Polyargyrite $Ag_{24}Sb_2S_{15}$
Polybasite Ag_9SbS_6
Polytelite $(PbAgFeZn)_4Sb_2S_7$?
Pyrargyrite Ag_3SbS_3
[Pyrostilpnite Ag_3SbS_3]
Rathite Pb, As, Sb, S ?
[Richmondite $R_4Sb_2S_9$ (R = Pb, Cu, Ag, Fe, Zn)]
[Sampsonite $(Ag_4Mn)Sb_2S_6$]
Semseyite $Pb_7Sb_8S_{16}$
Stephanite Ag_5SbS_4
(Steinmannite) Pb(As, Sb, S)
Stibnite Sb_2S_3
Stylotypite $(Cu_2Ag_2Fe)_3Sb_2S_6$
Tetrahedrite $Cu_6Sb_2S_7$
Ullmannite NiSbS
Vrbaite $TlAs_2SbS_5$
Willyamite (CoNi)SbS
Zinkenite $PbSb_2S_4$

BISMUTH

Aikinite $PbCuBiS_3$
[Badenite $(CoFeNi)_3(AsBi)_2$]
Beegerite $Pb_3Bi_2S_6$
Bismuth Bi
Bismuthinite Bi_2S_3
Chilenite Ag_2Bi ?
Chiviatite $Pb_2Bi_6S_{11}$
Cosalite $Pb_2Bi_2S_5$
[Cuprobismutite $Cu_4Bi_2S_{15}$]
Dognacskaite Bi, Cu, S ?
[Eichbergite $(CuFe)Bi_2Sb_2S_5$]
Emplectite $CuBiS_2$
Galenobismutite $PbBi_2S_4$
[Grünlingite Bi_4TeS_3]
Guanajuatite Bi_2Se_3
Hauchecornite $(NiCo)_7(Bi, S, Sb)_8$
[Histrixite $Cu_3Fe_3Bi_{10}Sb_2S_{27}$?]
Kallilite Ni, Bi, S ? (+Sb, As)
Klaprotholite $Cu_6Bi_4S_9$
Kobellite $Pb_2(BiSb)_2S_5$ (mixture?)
Lillianite $Pb_3Bi_2S_6$
Matildite $AgBiS_2$
[Platynite $PbBi_2S_3$]
Plenargyrite $AgBiS_2$?
Rezbanyite $Pb_4Bi_{10}S_{19}$
Schapbachite $PbAg_2Bi_2S_4$? (mixture)
Schirmerite $(Ag_2Pb)_3Bi_4S_9$
Tapalpaite $3\,Ag_2(S, Te)\cdot Bi_2(STe)_3$
Tetradymite $Bi_2(TeS)_3$
[Von Diestite Ag, Bi, Te ?]
[Weibullite $Pb_2Bi_4S_6Se_3$]
Wittichenite Cu_3BiS_3

CADMIUM

[Greenockite CdS]

CALCIUM

[Oldhamite CaS]

CHROMIUM

Chromite $FeCr_2O_4$
[Daubreelite $FeCr_2S_4$]

COBALT

[Badenite $(CoFeNi)_3(AsBi)_2$]
Cobaltite CoAsS
Glaucodot (CoFe)AsS
Hauchecornite $(NiCo)_7(Bi, S, Sb)_8$
Linnaeite Co_3S_4
Safflorite $CoAs_2$
Skutterudite $CoAs_3$
Smaltite $CoAs_2$
[Sychnodymite $(CoCu)_4S$] ?
Willyamite (CoNi)SbS

COPPER

Aikinite $PbCuBiS_3$
Algodonite Cu_6As (mixture)
Berzelianite Cu_2Se
Bornite Cu_5FeS_4
Bournonite $(PbCu_2)_2Sb_2S_6$
"Bronze Enargite" (CuSn), (SbAs), S ?
Chalcocite Cu_2S
Chalcopyrite $CuFeS_2$
Chalcostibite $CuSbS_2$
Chalmersite $CuFe_2S_3$
Copper Cu
Covellite CuS
Crookesite $(CuTlAg)_2Se$
Cuprite Cu_2O
[Cuprobismutite $Cu_6Bi_8S_{15}$]
Cuprodescloizite $(PbZnCu)_4V_2O_9 \cdot H_2O$
Delafossite Cu, Fe, O
Dognacskaite Bi, Cu, S ?
Domeykite Cu_3As (+Sb) (mixture)
[Eichbergite $(CuFe)Bi_2Sb_2S_5$]
Emplectite $CuBiS_2$
Enargite Cu_3AsS_4
[Epigenite $R_7As_2S_{12}$ (R = 8 Cu + 3 Fe)]
Eucairite $Cu_2Se \cdot Ag_2Se$
Famatinite Cu_3SbS_4
Freibergite $(CuAg)_6Sb_2S_7$
Guejarite $Cu_2Sb_4S_7$
[Histrixite $Cu_5Fe_2Bi_{14}Sb_4S_{27}$ (mixture)]
Horsfordite Cu_5Sb
[Hutchinsonite Tl, Ag, Cu, Pb, As, S ?]
Jalpaite $Cu_2S \cdot 3\ Ag_2S$
Klaprotholite $Cu_6Bi_4S_9$
Lengenbachite $Pb_6(AgCu)_2As_4S_{13}$
Luzonite Cu_3AsS_4
Mohawkite Cu_3As (mixture)
Regnolite $Cu_7As_2S_{12}$
[Richmondite $R_6Sb_2S_9$ (R = Pb, Cu, Ag, Fe, Zn)]
Rickardite Cu_4Te_3
Seligmannite $CuPbAsS_3$
Stannite Sn, Cu, Fe, Zn, S ?
Stromeyerite $(AgCu)_2S$
Stylotypite $(Cu_2Ag_2Fe)_3Sb_2S_6$
Sulvanite Cu_3VS_4
[Sychnodymite $(CoCu)_6S_8$?]
Tennantite $Cu_6As_2S_7$
Tenorite CuO
Tetrahedrite $Cu_6Sb_2S_7$
Umangite Cu_3Se_2
Whitneyite Cu_9As
Wittichenite Cu_3BiS_3

GERMANIUM

Argyrodite Ag_8GeS_6
[Canfieldite $Ag_8(SnGe)S_6$]

GOLD

Calaverite $AgAuTe_2$
Gold Au
Kalgoorlite $HgAu_2Ag_4Te_6$
Nagyagite $Au_2Pb_{10}Sb_2Te_6S_{15}$
Petzite $(AgAu)_2Te$
[Speculite AgAuTe]
Sylvanite $AgAuTe_2$

IRON

[Argentopyrite Ag, Fe, S ?]
Argyropyrite Ag, Fe, S, As ?
Arsenopyrite FeAsS
[Badenite $(CoFeNi)_3(AsBi)_2$]
Berthierite $FeSb_2S_4$
Bornite Cu_5FeS_4
Chalcopyrite $CuFeS_2$
Chalmersite $CuFe_2S_3$
Chromite $FeCr_2O_4$
Cylindrite $3\ PbSnS_2 + SnFeSb_2S_6$
[Daubreelite $FeCr_2S_4$]
Delafossite Cu, Fe, O
[Eichbergite $(CuFe)Bi_2Sb_2S_5$]
[Epigenite $R_7As_2S_{12}$ (R = 8 Cu + 3 Fe)]
Frankeite $3\ PbSnS_2 + Pb_2FeSb_2S_6$
Franklinite $Fe_2ZnMn_2O_4$
Frieseite $AgFe_2S_3$
Glaucodot (CoFe)AsS
Hematite Fe_2O_3
[Histrixite $Cu_5Fe_2Bi_{14}Sb_4S_{27}$ (mixture)]
Ilmenite $FeTiO_3$
Limonite $2\ Fe_2O_3 \cdot 3\ H_2O$
Löllingite $FeAs_2$
Magnetite Fe_3O_4
Marcasite FeS_2
Pentlandite (FeNi)S
Polytelite $(PbAgFeZn)_4Sb_2S_7$?
Pyrite FeS_2
Pyrrhotite $FeS(S)_x$
[Richmondite $R_6Sb_2S_9$ (R = Pb, Cu, Ag, Fe, Zn)]
Stannite (Sn, Cu, Fe, Zn), S
Sternbergite $Ag_2Fe_6S_8$
Stylotypite $(Cu_2Ag_2Fe)_3Sb_2S_6$
[Troilite FeS]

LEAD

Aikinite $PbCuBiS_3$
Altaite PbTe
Andorite $Pb_2Ag_2Sb_6S_9$
Baumhauerite $Pb_4As_6S_{13}$
Beegerite $Pb_6Bi_2S_9$
Boulangerite $Pb_5Sb_2S_8$
Bournonite $(PbCu_2)_2Sb_2S_6$
Brogniardite $PbAg_2Sb_2S_5$?
Chiviatite $Pb_2Bi_6S_{11}$
Clausthalite PbSe
Cosalite $Pb_2Bi_2S_5$
Cuprodescloizite $(PbZnCu)_4V_2O_8 \cdot H_2O$
Cylindrite $3\,PbSnS_2 + SnFeSb_2S_6$
[Diaphorite $(PbAg_2)_3Sb_4S_{11}$]
Dufrenoysite $Pb_2As_2S_5$
Epiboulangerite $Pb_5Sb_2S_8$
Frankeite $3\,PbSnS_2 + Pb_2FeSb_2S_6$
Freieslebenite $(PbAg_2)_3Sb_4S_{11}$
Galena PbS
Galenobismutite $PbBi_2S_4$
Geocronite $Pb_5Sb_2S_8$
Guitermannite $Pb_3As_2S_6$
[Hutchinsonite Tl, Ag, Cu, Pb, As, S ?]
Jamesonite $Pb_2Sb_2S_5$
Jordanite $Pb_4As_2S_7$
Kobellite $Pb_2(BiSb)_2S_5$ (mixture?)
Lehrbachite $PbSe + HgSe$
Lengenbachite $Pb_6(AgCu)_2As_4S_{13}$
Lillianite $Pb_3Bi_2S_6$
[Liveingite $Pb_6As_8S_{17}$]
Meneghinite $Pb_4Sb_2S_7$
Nagyagite $Au_2Pb_{10}Sb_2Te_6S_{15}$
Naumannite $(Ag_2Pb)Se$
Plagionite $Pb_5Sb_8S_{17}$
[Platynite $PbBi_2S_3$]
Polytelite $(PbAgFeZn)_4Sb_2S_7$?
Rathite Pb, As, Sb, S ?
Rezbanyite $Pb_4Bi_{10}S_{19}$
[Richmondite $R_4Sb_2S_9$ (R = Pb, Cu, Ag, Fe, Zn)]
Sartorite $PbAs_2S_4$
Schapbachite $PbAg_2Bi_2S_5$ (mixture)
Schirmerite $(Ag_2Pb)_3Bi_4S_9$
Seligmannite $CuPbAsS_3$
Semseyite $Pb_9Sb_8S_{16}$
Steinmannite Pb(As, Sb, S)
Teallite $PbSnS_2$
Uraninite U, O, Pb, La, Th, Di, Y, etc. ?
[Weibullite $Pb_2Bi_4S_5Se_3$]
Zinkenite $PbSb_2S_4$

MANGANESE

Alabandite MnS
Erythrozincite (MnZn)S ?
Franklinite $Fe_2ZnMn_2O_4$
Hauerite MnS_2
Psilomelane H_4MnO_5
[Sampsonite $(Ag_4Mn)Sb_2S_6$]

MERCURY

Cinnabar HgS
Coloradoite HgTe
Kalgoorlite $HgAu_2Ag_6Te_6$
Lehrbachite $PbSe + HgSe$
Livingstonite $HgSb_4S_7$
Metacinnabarite HgS
Onofrite Hg(SSe)
Tiemannite HgSe

MOLYBDENUM

Molybdenite MoS_2

NICKEL

[Badenite $(CoNiFe)_2(AsBi)_3$]
Breithauptite NiSb
Chloanthite $NiAs_2$
Gersdorffite NiAsS
Hauchecornite $(NiCo)_7(Bi, S, Sb)_8$
Kallilite NiBiS(AsSb)
Maucherite Ni_2As_3
Melonite $NiTe_2$
Millerite NiS
Niccolite NiAs
Pentlandite (FeNi)S
Polydymite Ni_4S_5
Rammelsbergite $NiAs_2$
Ullmannite NiSbS
Willyamite (CoNi)SbS

OXYGEN

Cassiterite SnO_2
Chromite $FeCr_2O_4$
Cuprite Cu_2O
Cuprodescloizite $(PbZnCu)_4V_2O_8 \cdot H_2O$
Delafossite Cu, Fe, O
Franklinite $Fe_2ZnMn_2O_4$
Hematite Fe_2O_3
Ilmenite $FeTiO_3$
Kermesite Sb_2S_2O
Limonite $2\,Fe_2O_3 \cdot 3\,H_2O$
Magnetite Fe_3O_4
Psilomelane H_4MnO_5
Rutile TiO_2
Tenorite CuO
Uraninite U, O, Pb, La, Th, Di, Y, etc. ?
Voltzite Zn_5S_4O

PLATINUM

Sperrylite $PtAs_2$

RUTHENIUM

[Laurite $RuAs_2$]

SELENIUM

Aguilarite $Ag_2S \cdot Ag_2Se$
Berzelianite Cu_2Se
Clausthalite PbSe
Crookesite $(CuTlAg)_2Se$
Eucairite $(CuAg)_2Se$
Guanajuatite Bi_2Se_3
Lehrbachite PbSe + HgSe
Naumannite $(Ag_2Pb)Se$
Onofrite HgSSe
Tiemannite HgSe
Umangite Cu_3Se_2
[Weibullite $Pb_2Bi_4S_5Se_3$]

SILVER

Aguilarite $Ag_2S \cdot Ag_2Se$
Andorite $Pb_2Ag_3Sb_6S_9$
Argentite Ag_2S
[Argentopyrite Ag, Fe, S ?]
Argyrodite Ag_8GeS_6
Argyropyrite Ag, Fe, S, As ?
Brogniardite $PbAg_2Sb_2S_5$?
Calaverite $AgAuTe_2$
[Canfieldite $Ag_8(SnGe)S_6$]
Chilenite Ag_4Bi
Crookesite $(CuTlAg)_2Se$
[Diaphorite $(PbAg_2)_3Sb_4S_{11}$]
Dyscrasite Ag_3Sb
Eucairite $(CuAg)_2Se$
Freieslebenite $(PbAg_2)_3Sb_4S_{11}$
Freibergite $(CuAg)_6Sb_2S_7$
Frieseite, $AgFe_2S_3$
Hessite Ag_2Te
Huntilite Ag_2As ?
[Hutchinsonite Tl, Ag, Cu, Pb, As, S ?]
Jalpaite $3\,Ag_2S \cdot Cu_2S$
Kalgoorlite $HgAu_2Ag_4Te_6$
Lengenbachite $Pb_6(AgCu)_2As_4S_{13}$
Matildite $AgBiS_2$
Miargyrite $AgSbS_2$
Naumannite $(Ag_2Pb)Se$
Pearceite Ag_9AsS_6
Petzite $(AgAu)_2Te$
Plenargyrite $AgBiS_2$? (mixture)
Polyargyrite $Ag_{14}Sb_2S_{11}$
Polybasite Ag_9SbS_6
Polytelite $(PbAgFeZn)_9Sb_2S_7$?
Proustite Ag_3AsS_3
Pyrargyrite Ag_3SbS_3
[Pyrostilpnite Ag_3SbS_3]
[Richmondite $R_6Sb_2S_9$ (R = Pb, Cu, Ag, Fe, Zn)]
[Sampsonite $(Ag_4Mn)Sb_2S_6$]
Schapbachite $PbAg_2Bi_2S_5$ (mixture)
Schirmerite $(Ag_2Pb)_3Bi_2S_6$
Silver Ag
[Smithite $AgAsS_2$]
[Speculite AgAuTe]
Stephanite Ag_5SbS_4
Sternbergite $Ag_2Fe_2S_3$
Stromeyerite $(AgCu)_2S$
Stützite Ag_4Te ?
Stylotypite $(Cu_2Ag_2Fe)_3Sb_2S_6$
Sylvanite $AuAgTe_2$
Tapalpaite $3\,Ag_2(STe) \cdot Bi_2(STe)_3$
[Trechmannite $AgAsS_2$]
[Von Diestite Ag, Bi, Te ?]
[Xanthoconite Ag_3AsS_4]

TELLURIUM

Altaite PbTe
Calaverite $AgAuTe_2$
Coloradoite HgTe
[Grünlingite Bi_4TeS_2 ?]
Hessite Ag_2Te
Kalgoorlite $HgAu_2Ag_4Te_4$
Melonite Ni_2Te_2
Nagyagite $Au_2Pb_{10}Sb_2Te_6S_{14}$
Petzite $(AgAu)_2Te$
Rickardite Cu_4Te_3
[Speculite AgAuTe]
Stützite Ag_4Te ?
Sylvanite $AuAgTe_2$
Tapalpaite $3\,Ag_4(STe)\cdot Bi_2(STe)_3$
Tellurium Te
Tetradymite $Bi_2(TeS)_3$
[Von Diestite Ag, Bi, Te ?]

THALLIUM

Crookesite $(CuTlAg)_2Se$
[Hutchinsonite Tl, Ag, Cu, Pb, As, S ?]
Lorandite $TlAsS_2$
Vrbaite $TlAs_2SbS_5$

THORIUM

(with Lanthanum, Yttrium, Nitrogen, etc.)

Uraninite U, O, Y, N, Di, Th, La, etc.

TIN

"Bronze Enargite" (CuSn), (SbAs), S ?
Cassiterite SnO_2
Cylindrite $3\,PbSnS_2 + SnFeSb_2S_6$
Frankeite $3\,PbSnS_2 + Pb_2FeSb_2S_6$
Stannite Sn, Cu, Fe, Zn, S
Teallite, $PbSnS_2$
[Canfieldite $Ag_8(SnGe)S_6$]

TITANIUM

Ilmenite $FeTiO_3$
Rutile TiO_2

URANIUM

Uraninite U. O, Pb, Y, N, Di, La, Th, etc.

VANADIUM

Cuprodescloizite $(PbZnCu)_4V_2O_9\cdot H_2O$
[Patronite VS_4 ?]
Sulvanite Cu_3VS_4

ZINC

Cuprodescloizite $(PbZnCu)_4V_2O_9\cdot H_2O$
Erythrozincite (ZnMn)S ?
Franklinite $Fe_2ZnMn_2O_4$
Polytelite $(PbAgFeZn)_4Sb_2S_7$
[Richmondite $R_6Sb_2S_9$ (R = Pb, Cu, Ag, Fe, Zn)]
Sphalerite ZnS
Stannite Sn, Cu, Fe, Zn, S
Voltzite Zn_2S_2O
Wurtzite ZnS

INDEX OF MINERALS

The number in parentheses after each name indicates the number of localities from which material has been studied. (n) indicates more than 5 localities. The letter or symbol, in the case of single specimens, indicates the probable value of the specimen as a representative of its species. G = reliable. F = fairly reliable. ? = doubtful.

Mineral	Page
Aguilarite 1) G	106
Aikinite (1) G	101
Alabandite (3)	96
Algodonite (mixture) (1)	37
Cream constituent	74
Gray constituent	96
Alloclasite (mixture ?) (1)	37
Altaite (3)	128
Andorite (1) G	134
Animikite (mixture ?) (1)	37
Argentite (4)	107
Argyrodite (2)	105
Argyropyrite (1) ?	101
Arsenic (2)	136
Arsenopyrite (n)	82
Barnhardtite (mixture) (1)	37
Baumhauerite (1) G	108
Beegerite (1) G	134
Berthierite (3)	103
Berzelianite (1) G	131
Bismuth (n)	125
Bismuthinite (3)	130
Antimonial (1) G	131
Bornite (n)	65
Boulangerite (2)	135
Bournonite (4)	92
Breithauptite	66
Brogniardite (1) ?	37, 110
Calaverite (1) G	124
Carrollite (mixture ?) (1)	37
Cassiterite (3)	146
Chalcocite (n)	107
Chalcopyrrhotite (mixture) (1)	37
Chalcostibite (1) G	102
Chalcopyrite (n)	62
Chalmersite (3)	72
Chilenite (1) G	125
Chiviatite (1) G	120
Chloanthite (2)	85
Chromite (2)	146
Cinnabar (2)	141
Clausthalite (1) G	128
Cobaltite (2)	86
Coloradoite (1) G	106
Copper (n)	67
Cosalite (1) F	122
Covellite (n)	58
Crookesite (1) F	108
Cubanite (mixture) (4)	37
Cuprite (n)	117
Cuprodescloizite (1) G	149
Cylindrite (1) G	110
Delafossite (1) G	92
Dognacskaite (1) G	135
Domeykite (2)	37, 125
Dufrenoysite (1) G	142
Dyscrasite (2)	125
Emplectite (3)	122
Enargite (n)	95
Epiboulangerite (1) G	134
Erythrozincite (1) G	148
Eucairite (1) G	130
Famatinite (3) ?	99
Frankeite (1) G	110
Franklinite (1) G	144
Freibergite (2)	94
Freieslebenite (1) G	134
Galena (n)	133
Galenobismutite (1) ?	130
Geocronite (1) F	132
Gersdorffite (2)	88
Glaucodot (1) G	87
Gold (n)	62
Guanajuatite (1) G	120
Guejarite (1) G	103
Guitermanite (1) G	134

Mineral	Page
Harrisite (pseudomorph) (1) G	38
Hauchecornite (2)	79
Hauerite (2)	94
Hematite (n)	90
Hessite (2)	138
Homichlin (mixture) (1) G	38
Horsfordite (1) G	135
Huntilite (1) F	119
Ilmenite (5)	90
Jalpaite (1) F	140
Jamesonite (2)	110
Jordanite ? (1) ?	134
Kalgoorlite (1) G	124
Kallilite (1) F	82
Kermesite (1) G	138
Keweenawite (mixture) (2)	38
Klaprotholite (mixture ?) (1) ?	38
Kobellite	38
Krennerite (1) G	124
Lehrbachite (1) F	131
Lengenbachite (1) G	141
Lillianite (1) G	133
Limonite (n)	146
Linnaeite (2)	79
Livingstonite (1) G	142
Löllingite (2)	84
Lorandite (1) G	150
Luzonite (3 ?)	98
Magnetite (n)	91
Marcasite (n)	78
Matildite (1) G	140
Maucherite (2)	79
Melonite (1) G	124
Meneghinite (1) G	132
Metacinnabarite (1) G	122
Miargyrite (1) G	115
Millerite (3)	63
Mohawkite (mixture) (1) G	38
Cream constituent	74
Gray constituent	97
Molybdenite (4)	104
Nagyagite (2)	134
Naumannite (1) G	128
Niccolite (n)	66
Onofrite (1) F	114
Orpiment (2)	105
Pearceite (1) F	105
Pentlandite (1) G	100
Petzite (2)	137
Plagionite (1) G	135
Plenargyrite (mixture) (1) F	38
Hard constituent	136
Soft constituent	116
Polyargyrite (1) G	114
Polybasite (3)	105
Polydymite (2)	82
Polytelite (1) ?	96
Proustite (n)	115
Psilomelane (2)	144
Pyrargyrite (6 ?)	115
Pyrite (n)	78
Pyrrhotite (n)	76
Rammelsbergite (1) G	85
Rathite (1) G	141
Realgar (3)	108
Regnolite (1) G	104
Rezbanyite (1) G	136
Rickardite (1) G	60
Rutile (2)	90
Safflorite (1) G	83
Sartorite (1) F	142
Schapbachite (mixture) (1) F	38
Hard constituent	137
Soft constituent	116
Schirmerite (1) F	141
Seligmannite (1) G	104
Semseyite (1) G	132
Silver (n)	118
Skutterudite (1) ?	83
Smaltite (3)	38, 83
Sperrylite (1) G	91
Sphalerite (n)	148
Stannite (3)	108
Steinmannite (var. Galena) (1) G	133
Stephanite (2)	142
Sternbergite (1) G	65
Stibnite (3)	138
Stromeyerite (3)	117
Stützite (1) G	114
Stylotypite (1) F	97
Sulvanite (1) G	72
Sylvanite (2)	122
Tapalpaite (mixture ?) (1) G	38, 125
Teallite (1) G	106
Tellurium (3)	130
Temiskamite (mixture) (1) G	38
Tennantite (n)	94
Tenorite (2)	92
Tetradymite (2) ?	133
Tetrahedrite (n)	94
Tiemannite (1) G	114
Ullmannite (1) G	84
Umangite (3)	60
Unknown minerals:	
Algodonite cream	74
gray	96
"Alloklas" from Orawitza	136
Argentiferous "jamesonite"	104

Mineral	Page
"Brogniardite" (near andorite)	134
Bluish white, Joachimsthal	115
Bluish white, Tonopah	114
"Bronze Enargite"	74
Coffee brown	65
Creamy bismuth mineral	126
Grayish bismuth mineral	97
"Hessite"	118
"Matildite" Japan	120
Mohawkite cream	74
gray	97
Orange "bornite"	64
"Petzite"	106
Pink mineral in mohawkite	76
Purple "bornite"	65
Purple "galena"	116
Plenargyrite, hard constituent	136
Soft constituent	116
Schapbachite, hard constituent	137
Schapbachite, soft constituent	116
"Tapalpaite" Gray	107
Pure white mineral, Bisbee	130
Uraninite (1) G	147
Voltzite (1) G	148
Vrbaite (1) G	115
Whitneyite (1) G	74
Willyamite (1) G	82
Wittichenite (1) F	121
Wurtzite (1) G	148
Zinkenite (2)	111

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